EXHIBIT 5

(Redacted)

(Unredacted Version To Be Filed Under Seal)

Expert Report of A. Dallas Wait, Ph.D.

Regarding:

Analytical Chemistry Aspects of Proposed PFAS Class

In the Matter of:

Kevin Hardwick *v*. 3M Company, *et al*., Civil Action No. 2:18-cv-1185

December 14, 2020

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www.gradientcorp.com
One Beacon Street, 17th Floor
Boston, MA 02108
617-395-5000

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Abbreviations

3M	3M Company
AGCCA	AGC Chemicals Americas, Inc.
Archroma	Archroma Management LLC
Arkema France	Arkema France, S.A.
CDC	Centers for Disease Control and Prevention
Chemours	The Chemours Company
CLIA	Clinical Laboratory Improvement Amendments of 1988
CV	Coefficient Variation
Daikin America	Daikin America, Inc.
Daikin Industries	Daikin Industries Ltd.
DuPont	E. I. du Pont de Nemours and Company
ERCO	Energy Resource Company, Inc.
FS	Feasibility Study
GC	Gas Chromatography
ILC	Interlaboratory Comparison
LC	Liquid Chromatography
LOD	Limit of Detection
LOQ	Limit of Quantification
MDL	Method Detection Limit
MeFOSAA	N-Methyl Perfluorooctane Sulfonamido Acetic Acid
µg/mL	Micrograms Per Milliliter
MS	Mass Spectrometry
ng/mL	Nanograms Per Milliliter
NHANES	National Health and Nutrition Examination Survey
NJDOH	New Jersey Department of Health
PFAA	Perfluoroalkyl Acid
PFAS	Perfluoroalkyl and Polyfluoroalkyl Substances
PFBS	Perfluorobutane Sulfonate
PFDA	Perfluorodecanoate
PFDoDA	Perfluorododecanoate
PFHpA	Perfluoroheptanoate
PFHxA	Perfluorohexanoate
PFHxS	Perfluorohexane Sulfonate
PFNA	Perfluorononanoate
PFOA	Perfluorooctanoate
PFOS	Perfluorooctane Sulfonate
PFUnA	Perfluoroundecanoate
pg/mL	Picograms Per Milliliter
ppb	Parts Per Billion

ppm	Parts Per Million
ppq	Parts Per Quadrillion
ppt	Parts Per Trillion
PQL	Practical Quantitation Limit
QA	Quality Assurance
RI	Remedial Investigation
RSD	Relative Standard Deviation
RL	Reporting Limit
Solvay	Solvay Specialty Polymers, USA, LLC
UNEP	United Nations Environment Programme
US EPA	United States Environmental Protection Agency
US FDA	United States Food and Drug Administration
VALID	Verifying Accurate Leading-Edge IVCT Development Act of 2020

1 Scope and Qualifications

I am a Principal and analytical chemistry expert with the consulting firm Gradient. In 1973, I earned a Bachelor of Science degree in chemistry from the University of Rhode Island and received a Ph.D. in organic chemistry from the same institution in 1980. For my first post-doctoral position, I was the Director of the Organic Chemistry Laboratory at Energy Resource Company, Inc. (ERCO) in Cambridge, Massachusetts. There, I was responsible for the management of the organic laboratory, which consisted of gas chromatography (GC), liquid chromatography (LC), GC-mass spectrometry (MS), and LC-MS instrumentation. I later held a position as the Vice President and Director of Analytical Services for ERCO, a division of ENSECO, where I was responsible for the overall direction and management of the organic, trace metal, and inorganic chemistry laboratories. After three years, I was promoted to Vice President and Technical Director of the ENSECO-ERCO Laboratory. During my tenure at ENSECO, under contract with the United States Environmental Protection Agency's (US EPA) Office of Solid Waste, I developed and evaluated analytical methodologies associated with the analysis of waste samples, often in support of delisting petitions. I have acted as Quality Assurance Officer for numerous remedial investigation/ feasibility study (RI/FS) programs that have been conducted throughout the United States; often dealing with difficult sampling, analysis, and regulatory issues. In addition, I coauthored portions of the 1982 second edition of US EPA's SW-846 Manual, titled "Test Methods for Evaluating Solid Waste," containing methods designed to determine hazardous waste characteristics. Also, under contract with US EPA, I managed its first Superfund contract for organics, its first isotope dilution GC/MS contract for organics in wastewater, and participated in its interlaboratory evaluation of six drinking water test methods. Since 1989, I have developed a data quality management practice at Gradient, which includes conducting forensic chemistry investigations, resolving product chemistry issues, designing sampling and analysis methods, and quality assurance (QA) programs, determining the reliability of measurements and sampling procedures, and providing regulatory comment. For instance, I was retained as a consulting expert to evaluate the quality, reliability, and usability of data generated for various environmental investigations conducted in response to the Deepwater Horizon oil spill event that occurred in the Gulf of Mexico during the spring of 2010. The evaluation included a top-down assessment of all sampling and analysis QA systems. I serve on the editorial board of two peer-reviewed journals, have published over 30 journal articles as well as three book chapters. I am also a member of numerous scientific work groups and science advisory boards involved in developing and evaluating sampling and analysis methods and QA programs, and I was recently the Chair of the US EPA Environmental Laboratory Advisory Board (ELAB). A true and correct copy of my *curriculum vitae* and testimony experience are attached herein as Appendices A and B, respectively. Gradient is compensated for my services at a rate of $390 per hour.

I was retained by 3M Company (3M), E. I. du Pont de Nemours and Company (DuPont), The Chemours Company (Chemours), Archroma Management LLC (Archroma), Arkema, Inc., Arkema France, S.A. (Arkema France), AGC Chemicals Americas, Inc. (AGCCA), Daikin Industries Ltd. (Daikin Industries), Daikin America, Inc. (Daikin America), and Solvay Specialty Polymers, USA, LLC (Solvay) in the matter of Kevin Hardwick *v.* 3M Company, *et al*., Civil Action No. 2:18-cv-1185 in the US District Court for the Southern District of Ohio, Eastern Division. I was asked to review the proposed class definition "any individual residing within the United States at the time of class certification for one year or more since 1977 with 0.05 parts per trillion (ppt) of PFOA and at least 0.05 ppt of any other PFAS in their blood serum," as stated in the motion for class certification.

This report sets forth my opinions with regard to the reasonableness and technical feasibility of testing for the perfluoroalkyl and polyfluoroalkyl substances (PFAS) levels in the proposed class definition. My opinions are based on my training and experience in organic, environmental, and analytical chemistry, and a review of the documents available as of the date of this report. Specific documents I have cited are presented in the References section. In addition, my opinions are informed by my extensive professional history and experience in data quality management. The types of information I relied upon for my analyses in this matter include the following.

- Case-specific documents, such as the complaint, the plaintiff's motion for class certification, Mr. Hardwick's transcript, blood sampling data, and data quality documentation.
- General guidance documents in the fields of clinical and analytical chemistry and data quality by agencies such as Centers for Disease Control and Prevention (CDC) including, among others, analytical methods, data validation guidelines, *etc*.
- Publicly available technical and regulatory documents that are not case-specific but provide data and information that are relevant to my analyses, including but not limited to information contained in the AR-226 US EPA Administrative Record for Perfluorinated Chemicals.
- Scientific literature, such as peer-reviewed journal articles and scientific textbooks regarding analytical methods and data quality related to PFAS.

I reserve the right to amend my opinions should additional information become available.

2 Opinions

2.1 The class definition is not consistent with current analytical capabilities. The proposed concentration criteria for the class, 0.00005 ng/mL, are orders of magnitude below current detection limits for perfluorooctanoate (PFOA) in blood serum, and the definition of perfluoroalkyl and polyfluoroalkyl substances (PFAS) includes chemicals for which no serum test methods are available.

The proposed definition of the class as stated in the plaintiff's motion for class certification is "any individual residing within the United States at the time of class certification for one year or more since 1977 with 0.05 parts per trillion (ppt) or more of PFOA and at least 0.05 ppt of any other PFAS in their blood serum" (Taft Stettinius & Hollister LLP, 2020). The proposed concentration criteria are problematic for two reasons: First, the proposed concentration criteria are orders of magnitude lower than current detection limits for perfluorooctanoate (PFOA) and other PFAS in blood serum, and second, analytical methods do not exist to measure every PFAS chemical in blood serum.

PFAS blood levels are typically reported in ng/mL or ppb (nanograms per milliliter or parts per billion). The proposed class concentration criteria, 0.05 ppt, are equivalent to 0.05 picograms per milliliter (pg/mL) or 0.00005 ng/mL (Figure 2.1). Concentrations this low cannot be measured by currently available analytical methods; they are below the method limits of detection (LODs) for PFAS in recent blood serum methods as summarized in Table 2.1. The LOD for a method is generally defined as the lowest concentration of an analyte that can be distinguished from blank concentrations or instrumental noise with a stated confidence value (typically 95% or 99%). For clinical laboratories,[1] laboratories that perform testing on specimens from humans, such as blood, body fluid, and tissues, there is no prescribed method for determining the LOD. Considerable disagreement appears in the literature regarding the terminology and calculation methods of detection and quantitation limits (Wait *et al.*, 2015). To avoid confusion, Table 2.1 includes a description of the detection limit calculation method used for each study (US FDA, 1996).

[1] Clinical laboratories are governed by the Clinical Laboratory Improvement Amendments of 1988 (CLIA) (US DHHS, 2017). CLIA's focus is on laboratory quality systems rather than specific test methods. CLIA requires laboratories to establish the LODs through method verification, but does not prescribe the method of calculation of the LOD (US DHHS, 2017). *In vitro* diagnostic tests are regulated by United States Food and Drug Administration (US FDA) under the Medical Device Amendments of 1976. US FDA maintains that this authority includes laboratory developed tests, or tests designed, manufactured, and used within a single laboratory, a position challenged by many laboratories. In practice, US FDA has not exercised regulatory oversight of laboratory developed tests (Genzen, 2019). The Verifying Accurate Leading-edge IVCT Development Act of 2020 (VALID), legislation introduced on March 5, 2020, would clarify US FDA's authority to review and approve laboratory developed tests. The US FDA (1996) "Guidance for Industry Q2B Validation of Analytical Procedures: Methodology" provides several methods for calculation of the LOD, based on either the signal to noise ratio or the standard deviation of the response and the slope.

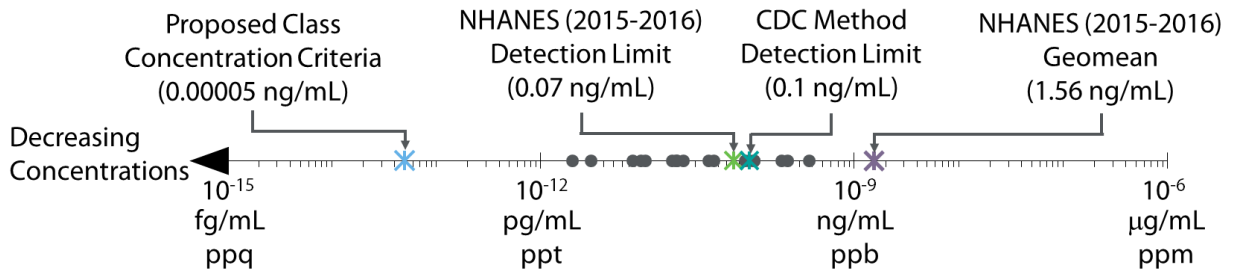

Figure 2.1 PFOA Concentration Comparison. Geomean = Geometric Mean; NHANES = National Health and Nutrition Examination Survey; PFOA = Perfluorooctanoate. Log scale number line comparing reported detection limits and concentrations of PFOA in serum. Grey dots represent Limits of Detection from the recent scientific literature (see Table 2.1).

The CDC has published PFAS methods developed in support of the National Health and Nutrition Examination Survey (NHANES) program (CDC, 2013, 2016, 2018a). The CDC methods are not regulatory promulgated methods. While there are promulgated methods available for testing PFAS in drinking water (US EPA methods 533 and 537.1), there is no analogous regulatory required or standard method for PFAS analysis in human serum or plasma. Clinical laboratories may follow CDC methods or their own laboratory developed tests. However, CDC methods are likely good examples of method performance levels achievable by a typical commercial clinical laboratory. The LOD for PFOA in CDC methods is 0.1 ng/mL (Table 2.1). The proposed concentration criteria for class certification (0.00005 ng/mL) are 2,000 times lower than current CDC methods detection limits (LOD = 0.1 ng/mL).

Clinical research laboratories have been able to achieve lower detection limits than the CDC. In Table 2.1, I have compiled reported LODs or Limits of Quantitation (LOQs) for recent blood serum or plasma methods and studies published in the scientific literature. Reported LODs for PFOA range from 0.002 ng/mL (Lee and Mabury, 2011) to 0.37 ng/mL (Reardon *et al*., 2019). The proposed concentration criteria (0.00005 ng/mL) are 40-7,400 times lower than LODs reported in recent scientific literature. Setting the proposed concentration criteria well below current detection limits will lead to ambiguous testing results. If a person's serum sample was not detected for PFOA at the CDC detection limit of 0.1 ng/mL, there would be no way to determine whether <0.1 ng/mL is greater than or less than the class concentration criteria of 0.00005 ng/mL.

[redacted]

[2] RL are the laboratory defined lowest concentration that can be quantified at a reasonable level of accuracy and precision, sometimes referred to as the Practical Quantitation Limit (PQL), or Limit of Quantitation (LOQ). Typically these are higher, sometimes much higher, than the method LOD. Samples under the RL are either not reported (as seen in this example) or reported as non-detect.

The current class definition also depends on the definition of "PFAS," because the definition imposes the concentration criteria on both PFOA and "and at least 0.05 ppt of any other PFAS in their blood serum." The class certification motion defines "PFAS" as:

> "PFAS" are synthetic, toxic per- and polyfluoroalkyl substances, including perfluorooctanoic acid ("PFOA") and perfluorooctane sulfonic acid ("PFOS") and related chemicals, including, but not limited to, those that degrade to PFOA and/or PFOS, and including, but not limited to, C3-C- 15 PFAS chemicals, such as perfluorohexanesulfonate (PFHxS), perfluorononanoate (PFNA), perfluorobutanesulfonate (PFBS), perfluorohexanoate (PFHxA), perfluoroheptanoate (PFHpA), perfluoroundecanoate (PFUnA), perfluorododecanoate (PFDoA), HFPA Dimer Acid (CAS # 13252-13-6/C3 Dimer Acid/P-08-508/FRD903/GX903/C3DA/GenX), and HFPA Dimer Acid Ammonium Salt (CAS# 62037-80-3/ammonium salt of C3 Dimer Acid/P-08-509/FRD902/GX902/GenX). (Taft Stettinius & Hollister LLP, 2020)

This definition is "not limited to" a specific list of chemicals, but potentially includes any PFAS chemical. A recent survey of Chemical Abstract Services Registry Numbers suggests there are approximately 4,700 PFAS-related compounds in commerce (OECD, 2018). Other estimates of the number of PFAS compounds range as high as 5,000-10,000 (ITRC, 2020), and these estimates may only increase as new products are brought to market and metabolites or breakdown products are identified. Analytical methods do not yet exist for the vast majority of PFAS compounds. Only a limited number of PFAS chemicals have been consistently analyzed in blood serum. The CDC methods include 8-12 PFAS analytes[3] (CDC, 2013, 2016, 2018a), and methods published in the recent scientific literature include between 1 to 43 analytes (Table 2.1). The ambiguity of the PFAS definition included in the class definition may lead to instances where the same blood sample measured in laboratories with different target analyte lists may or may not fall within the class definition.

2.2 Current clinical laboratories are not capable of consistently quantifying the class concentration criteria, and it would be an extremely onerous task for even research laboratories to reliably achieve that standard.

It is unlikely that commercial clinical laboratories could achieve a LOD of 0.00005 ng/mL in blood serum from individuals, and it would be extremely difficult even for research laboratories. The CDC method levels of detection (0.1 ng/mL for all analytes) have not changed in the last three method updates (CDC, 2013, 2016, 2018a). However, these detection limits have been sensitive enough to detect PFOA and PFOS consistently in serum from the general population, as demonstrated by the two most recent NHANES surveys (Table 2.2). The mean concentrations reported in the two most recent NHANES surveys are well above detection limits. The geometric mean of PFOA in serum was 1.56 ng/mL (2015-2016, n = 1,993) and 1.94 ng/mL (2013-2014, n = 2,165), more than an order of magnitude above the CDC methods detection limits and more than five orders of magnitude higher than the proposed class concentration criteria. The geometric means of PFOS in serum in these surveys were even higher, 4.72 ng/mL (2015-2016, n = 1,993) and 4.99 ng/mL (2013-2104, n = 2,165). Non-detection rates for PFOA and PFOS in both the 2015-2016 and 2013-2014 NHANES surveys were <1%. Non-detection rates in these surveys increase with chain lengths both higher and lower than C8.

[3] Perfluorodecanoate (PFDA), PFHxS, n-methyl perfluorooctane sulfonamido acetic acid (MeFOSAA), PFNA, perfluoroundecanoate (PFUnA), perfluorododecanoate (PFDoDA), PFOA, and PFOS (branched and linear isomers of PFOA and PFOS are included as one analyte).

Table 2.2 Rates of Non-Detection, Geomean, and 95th Percentile for Selected PFAS in Serum for NHANES 2013-2014 and 2015-2016 Adult Populations[a] Compared to Named Plaintiff Serum Data[b]

Analyte	NHANES 2015-2016 Adults					NHANES 2013-2014 Adults					Named Plaintiff	
	% ND	n	LOD[c] (ng/mL)	Geomean (ng/mL)	95th% (ng/mL)	% ND	n	LOD[c] (ng/mL)	Geomean (ng/mL)	95th% (ng/mL)	Result (ng/mL)	RL (ng/mL)
PFBS	NA	NA	NA	NA	NA	99.3	2,168	0.07	–	–	–	0.05
PFHxS	1.6	1,993	0.07	1.18	4.90	1,2	2,168	0.07	1.35	5.60	7.4	0.05
PFOS	0.6	1,993	0.07	4.72	18.3	0.9	2,165	0.07	4.99	18.5	8.1	0.5
MeFOSAA	60.7	1,993	0.07	–	0.600	55.5	2,168	0.07	–	0.600	NA	NA
PFHpA	NA	NA	NA	NA	NA	87.5	2,168	0.07	–	0.200	0.097	0.05
PFOA	0.8	1,993	0.07	1.56	4.17	0.8	2,165	0.07	1.94	5.57	2.2	0.5
PFNA	1.3	1,993	0.07	0.577	1.90	1.2	2,168	0.07	0.675	2.00	0.51	0.05
PFDA	33.9	1,993	0.07	0.154	0.700	21.0	2,168	0.07	0.185	0.700	NA	NA
PFUnA	62.3	1,993	0.07	–	0.400	56.5	2,168	0.07	–	0.500	NA	NA
PFDoDA	97.7	1,993	0.07	–	–	83.1	2,168	0.07	–	0.200	NA	NA

Notes:

– = Not Reported; CDC = Centers for Disease Control and Prevention; LOD = Limit of Detection; MeFoSAA = N-Methyl Perfluorooctane Sulfonamido Acetic Acid; n = Number of Analyses; NA = Not Analyzed; % ND = Percent Non-detects; NHANES = National Health and Nutrition Examination Survey; PFBS = Perfluorobutane sulfonate; PFDA = Perfluorodecanoate; PFDoDA = Perfluorododecanoate; PFHpA = Perfluoroheptanoate; PFHxS = Perfluorohexane Sulfonate; PFNA = Perfluorononanoate; PFOA = Perfluorooctanoate; PFOS = Perfluorooctane Sulfonate; PFUnA = Perfluoroundecanoate; RL = Reporting Limit.

(a) CDC (2018b, 2019a,b).

(b) NMS Labs (2018).

(c) While CDC methods report an LOD of 0.1 ng/mL, the NHANES dataset reports data down to the low end of the linear range or 0.07 ng/mL.

As shown in Table 2.2, researchers have pushed detection limits lower than CDC methods in recent years, but none have approached the class concentration criteria. Methodological development for PFAS in serum has instead focused on expanding analyte lists (Gao *et al*., 2018; Nakayama *et al*., 2020; Reardon *et al*., 2019), reducing sample volume requirements (Gao *et al*., 2018; Salihovic *et al*., 2020), or increasing the sample throughput (Gao *et al*., 2018). Gao *et al*. (2018) increased the number of analytes up to 43, nearly double that of other studies. Recently, for a select few PFAS, multiple laboratories have pushed sample volumes down to 25-50 µL (Table 2.2), and have even been able to obtain results from dried blood spots (Poothong *et al.*, 2018). These are blood volumes that can be obtained from a finger stick, rather than requiring a blood draw,[4] which is convenient for biomonitoring studies.

Some researchers have attempted to lower LODs with limited success. One technique commonly employed to lower detection limits is to try to eliminate sources of contamination and lower blank levels. Ultra-trace analysis of perfluoroalkyl acids (PFAAs) in seawater (LOD = 0.4-5.2 parts per quadrillion [ppq] or femtograms/mL)[5] was achieved by intensive blank analysis and elimination of all Teflon components in the sample preparation steps and within the LC/MS/MS instrument (Yamashita *et al*., 2004). Although Yamashita *et al*. (2004) were measuring PFAS in seawater, they are a good example of the level of effort required to reach the lowest LODs in all matrices. This sort of highly sophisticated and labor intensive identification and elimination of contamination sources is not practical or something a commercial clinical laboratory would typically do when current detection limits are adequate for detection in most serum samples.

Method modifications required to lower LODs can limit the suitability of the method for biomonitoring, which generates large numbers of samples to be analyzed on relatively short time scales. For example, Yu *et al*. (2017), which reported one of the lowest detection limits (0.001-0.006 ng/mL) of the serum studies summarized in Table 2.1, was a modification of the CDC method 6304.04 (CDC, 2013) by researchers in the New Jersey Department of Health (NJDOH) with the goal of reducing method LODs. Decreases in detection limits were achieved by optimizing analytical columns and gradient programs, and instituting rigorous cleaning programs to remove potential contaminants and interferences. While NJDOH researchers managed to reduce the analysis time from 15 to 10 minutes per sample, they recommended a maximum of 20 serum samples analyzed per day, followed by a 9-hour cleaning process. While they achieved lower LODs, the modifications placed severe limits on sample throughput, and made the NJDOH method unsuited for large scale biomonitoring purposes.

An alternate technique used to lower detection limits is to increase sample volume. This is easy to do for water samples, but much more difficult for blood. Yamashita *et al*., (2004) extracted a liter of seawater per sample to measure ultra-trace concentrations of PFAS in seawater, but this amount was more blood than a person can safely or comfortably donate at a time. Lee and Mabury (2011) were able to achieve similar detection limits as Yu *et al*. (2017) without onerous cleaning steps by extracting 2-3 mL of serum. Assuming that the detection limits scale linearly with sample volume, a clinical laboratory using one of the CDC methods would need 100 mL of serum per sample, or 200 mL of blood to lower detection limits to the class concentration criteria.[6] This is an onerous amount of blood for a typical person to give for testing or biomonitoring.

[4] Typical blood draw samples are 2.5-3 mL, and a typical blood donation is 500 mL. Blood is normally about 50% serum or plasma serum and plasma, both are the liquid portion of the blood, and both can be separated from blood cells by centrifugation. However, plasma is obtained before the blood has clotted (and is treated with an anticoagulant), and serum is obtained after blood has clotted.

[5] The LOD was evaluated for each sample based on the maximum blank concentration, the concentration factors, the sample volume, and a signal-to-noise ratio of 3.

[6] Based on CDC methods (CDC, 2013), LOD of 0.1 ng/mL and sample volume of 50 µL, the estimated volume required is calculated from the 0.1 ng/mL / 0.00005 ng/mL × 50 µL × 10^{-3} ml/µL = 100 mL.

Even if a serum method with a lower LOD could be developed, it would be difficult for laboratories to reliably quantify lower concentration samples. Interlaboratory studies in the past decade have shown poor reproducibility for blood plasma samples as concentrations approach detection limits. Results from an international Interlaboratory Comparison (ILC) study published in 2011 (van Leeuwen *et al*., 2011; Weiss *et al*., 2013) that included two plasma samples, showed that lower concentration analytes had much poorer percent relative standard deviations (RSDs) compared to higher concentration analytes. For example, for the two plasma samples, A and B, PFOA concentrations were 2.87 ng/mL (n = 22) and 2.94 ng/mL (n = 19) and had reported RSDs of 21% and 19%, respectively, while PFHpA with concentrations of 0.18 (n = 14) and 0.17 (n=14) mg/mL had reported RSDs of 127% and 98%, respectively. The organizers attributed the large RSD values to analyte concentrations being below the LOD for some of the participating laboratories (van Leeuwen *et al*., 2011). The United Nations Environment Programme (UNEP) Stockholm Convention on Persistent Organic Pollutants requires that participating laboratories be able to measure persistent organic pollutants with RSD of 25% (Fiedler *et al*., 2020). PFAS compounds were included in the 2012/2013 and 2016/2017 assessments (Fiedler *et al*., 2020). In plasma samples the RSD for many PFAS analytes dropped between the 2012/2013 and 2016/2017 assessments, suggesting the interlaboratory reproducibility is improving; however, for PFOA the coefficient variant (CV) increased from 10% to 24% between 2012/2013 and 2016/2017, likely related to the lower concentrations in the later study (concentrations were 72.7 and 1.18 ppb in 2012/2013 and 2016/2017, respectively) (Fiedler *et al*., 2020). These studies demonstrate that samples with concentrations that approach the LOD can be difficult for laboratories to reliably quantify.

3 Attestation

I declare under penalty of perjury that the foregoing is true and correct.

_____ executed this day ___December 14, 2020___

A. Dallas Wait, Ph.D.
Gradient

References

Bartolome, M; Gallego-Pico, A; Huetos, O; Lucena, MA; Castano, A. 2016. "A fast method for analysing six perfluoroalkyl substances in human serum by solid-phase extraction on-line coupled to liquid chromatography tandem mass spectrometry." *Anal. Bioanal. Chem.* 408(8):2159-2170. doi: 10.1007/s00216-016-9319-0.

Centers for Disease Control and Prevention (CDC). 2013. "Laboratory Procedure Manual: Polyfluorinated Compounds in Serum, NHANES 2011-2012 (Revised)." National Center for Environmental Health. 42p., November 1. Accessed at https://www.cdc.gov/nchs/data/nhanes/nhanes_11_12/pfc_g_met.pdf.

Centers for Disease Control and Prevention (CDC). 2016. "Laboratory Procedure Manual: Perfluoroalkyl and Polyfluoroalkyl Substances in Serum, NHANES 2013-2014." National Center for Environmental Health, Division of Laboratory Sciences, Organic Analytical Toxicology Branch, Method No. 6304.06, 42p., July. Accessed at https://wwwn.cdc.gov/nchs/data/nhanes/2013-2014/labmethods/PFAS_H_MET.pdf.

Centers for Disease Control and Prevention (CDC). 2018a. "Laboratory Procedure Manual: Perfluoroalkyl and Polyfluoroalkyl Substances in Serum, NHANES 2015-2016." National Center for Environmental Health, Division of Laboratory Sciences, Organic Analytical Toxicology Branch, Method No. 6304.08, 44p. Accessed at https://wwwn.cdc.gov/nchs/data/nhanes/2015-2016/labmethods/PFAS_I_MET.pdf.

Centers for Disease Control and Prevention (CDC). 2018b. "NHANES 2015-2016 Dietary Data." July. Accessed at https://wwwn.cdc.gov/nchs/nhanes/Search/DataPage.aspx?Component=Dietary&CycleBeginYear=2015.

Centers for Disease Control and Prevention (CDC). 2019a. "Fourth National Report on Human Exposure to Environmental Chemicals (Revised - Updated Tables, January 2019). Volume One." 866p. January.

Centers for Disease Control and Prevention (CDC). 2019b. "NHANES 2013-2014 Laboratory Data." April. Accessed at https://wwwn.cdc.gov/nchs/nhanes/Search/DataPage.aspx?Component=Laboratory&CycleBeginYear=2013.

Fiedler, H; van der Veen, I; de Boer, J. 2020. "Global interlaboratory assessments of perfluoroalkyl substances under the Stockholm Convention on persistent organic pollutants." *Trends Analyt. Chem.* 124:115459. doi: 10.1016/j.trac.2019.03.023.

Gao, K; Fu, J; Xue, Q; Li, Y; Liang, Y; Pan, Y; Zhang, A; Jiang, G. 2018. "An integrated method for simultaneously determining 10 classes of per- and polyfluoroalkyl substances in one drop of human serum." *Anal. Chim. Acta* 999:76-86. doi: 10.1016/j.aca.2017.10.038.

Genzen, JR. 2019. "Regulation of laboratory-developed tests." *Am. J. Clin. Pathol.* 152(2):122-131. doi: 10.1093/ajcp/aqz096.

Gerona, RR; Schwartz, JM; Pan, J; Friesen, MM; Lin, T; Woodruff, TJ. 2018. "Suspect screening of maternal serum to identify new environmental chemical biomonitoring targets using liquid chromatography-quadrupole time-of-flight mass spectrometry." *J. Expo. Sci. Environ. Epidemiol.* 28(2):101-108. doi: 10.1038/jes.2017.28.

Glynn, A; Kotova, N; Dahlgren, E; Lindh, C; Jakobsson, K; Gyllenhammar, I; Lignell, S; Nalsen, C. 2020. "Determinants of serum concentrations of perfluoroalkyl acids (PFAAs) in school children and the contribution of low-level PFAA-contaminated drinking water." *Environ. Sci. Process. Impacts* 22(4):930-944. doi: 10.1039/c9em00497a.

Harada, KH; Fujii, Y; Zhu, J; Zheng, B; Cao, Y; Hitomi, T. 2020. "Analysis of perfluorooctanesulfonate isomers and other perfluorinated alkyl acids in serum by in-port arylation gas chromatography negative chemical ionization-mass spectrometry." *Environ. Sci. Technol. Lett.* 7(4):259-265. doi: 10.1021/acs.estlett.0c00133.

Honda, M; Robinson, M; Kannan, K. 2018. "A rapid method for the analysis of perfluorinated alkyl substances in serum by hybrid solid-phase extraction." *Environ. Chem.* 15(1-2):92-99.

Hu, XC; Dassuncao, C; Zhang, X; Grandjean, P; Weihe, P; Webster, GM; Nielsen, F; Sunderland, EM. 2018. "Can profiles of poly- and Perfluoroalkyl substances (PFASs) in human serum provide information on major exposure sources?" *Environ. Health* 17(1):11. doi: 10.1186/s12940-018-0355-4.

Huber, S; Brox, J. 2015. "An automated high-throughput SPE micro-elution method for perfluoroalkyl substances in human serum." *Anal. Bioanal. Chem*. 407(13):3751-3761. doi: 10.1007/s00216-015-8601-x.

Interstate Technology and Regulatory Council (ITRC). 2020. "Per- and Polyfluoroalkyl Substances (PFAS) (Technical/Regulatory Guidance)." Per- and Polyfluoroalkyl Substances (PFAS) Team, 380p., April. Accessed at https://pfas-1.itrcweb.org/wp-content/uploads/2020/04/ITRC_PFAS_TechReg_April 2020.pdf.

Kato, K; Kalathil, AA; Patel, AM; Ye, X; Calafat, AM. 2018. "Per- and polyfluoroalkyl substances and fluorinated alternatives in urine and serum by on-line solid phase extraction–liquid chromatography–tandem mass spectrometry." *Chemosphere* 209:338-345. doi: 10.1016/j.chemosphere.2018.06.085.

Koponen, J; Kiviranta, H. 2019. "Quantitation of perfluoroalkyl acids, parabens and cotinine from single low volume serum sample by validated analytical method." *Int. J. Environ. Anal. Chem*. 99(13):1268-1285. doi: 10.1080/03067319.2019.1618850.

Lee, H; Mabury, SA. 2011. "A pilot survey of legacy and current commercial fluorinated chemicals in human sera from United States donors in 2009." *Environ. Sci. Technol.* 45(19):8067-8074. doi: 10.1021/es200167q.

Miaz, LT; Plassmann, MM; Gyllenhammar, I; Bignert, A; Sandblom, O; Lignell, S; Glynn, A; Benskin, JP. 2020. "Temporal trends of suspect- and target-per/polyfluoroalkyl substances (PFAS), extractable organic fluorine (EOF) and total fluorine (TF) in pooled serum from first-time mothers in Uppsala, Sweden, 1996-2017." *Environ. Sci. Process. Impacts* 22(4):1071-1083. doi: 10.1039/c9em00502a.

Mottaleb, MA; Petriello, MC; Morris, AJ. 2020. "High-throughput UHPLC-MS/MS measurement of per- and poly-fluorinated alkyl substances in human serum." *J. Anal. Toxicol.* 44 (4) :339-347. doi: 10.1093/jat/bkz097.

Nakayama, SF; Isobe, T; Iwai-Shimada, M; Kobayashi, Y; Nishihama, Y; Taniguchi, Y; Sekiyama, M; Michikawa, T; Yamazaki, S; Nitta, H; Oda, M; Mitsubuchi, H; Sanefuji, M; Ohga, S; Mise, N; Ikegami, A; Suga, R; Shimono, M. 2020. "Poly- and perfluoroalkyl substances in maternal serum: Method development and application in Pilot Study of the Japan Environment and Children's Study." *J. Chromatogr. A* 1618:460933. doi: 10.1016/j.chroma.2020.460933.

NMS Labs. 2018. "Blood test results for Kevin Hardwick." 4p., October 16.

Organisation for Economic Co-operation and Development (OECD). 2018. "Toward a New Comprehensive Global Database of Per- and Polyfluoroalkyl Substances (PFASs): Summary Report on Updating the OECD 2007 List of Per- and Polyfluoroalkyl Substances (PFASs)." Environment Directorate, Joint Meeting of the Chemicals Committee and the Working Party on Chemicals, Pesticides and Biotechnology, ENV/JM/MONO(2018)7; OECD Series on Risk Management No. 39, 24p., May 4. Accessed at https://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=ENV-JM-MONO(2018)7&doclanguage=en.

Pan, Y; Zhu, Y; Zheng, T; Cui, Q; Buka, SL; Zhang, B; Guo, Y; Xia, W; Yeung, LW; Li, Y; Zhou, A; Qiu, L; Liu, H; Jiang, M; Wu, C; Xu, S; Dai, J. 2017. "Novel chlorinated polyfluorinated ether sulfonates and legacy per-/polyfluoroalkyl substances: Placental transfer and relationship with serum albumin and glomerular filtration rate." *Environ. Sci. Technol.* 51(1):634-644. doi: 10.1021/acs.est.6b04590.

Poothong, S; Lundanes, E; Thomsen, C; Haug, LS. 2017. "High throughput online solid phase extraction-ultra high performance liquid chromatography-tandem mass spectrometry method for polyfluoroalkyl phosphate esters, perfluoroalkyl phosphonates, and other perfluoroalkyl substances in human serum, plasma, and whole blood." *Anal. Chim. Acta* 957:10-19. doi: 10.1016/j.aca.2016.12.043.

Poothong, S; Papadopoulou, E; Lundanes, E; Padilla-Sanchez, JA; Thomsen, C; Haug, LS. 2019. "Dried blood spots for reliable biomonitoring of poly- and perfluoroalkyl substances (PFASs)." *Sci. Total Environ.* 655:1420-1426. doi: 10.1016/j.scitotenv.2018.11.214.

Reardon, AJF; Khodayari Moez, E; Dinu, I; Goruk, S; Field, CJ; Kinniburgh, DW; MacDonald, AM; Martin, JW. 2019. "Longitudinal analysis reveals early-pregnancy associations between perfluoroalkyl sulfonates and thyroid hormone status in a Canadian prospective birth cohort." *Environ. Int.* 129:389-399. doi: 10.1016/j.envint.2019.04.023.

Salihovic, S; Dickens, AM; Schoultz, I; Fart, F; Sinisalu, L; Lindeman, T; Halfvarson, J; Oresic, M; Hyotylainen, T. 2020. "Simultaneous determination of perfluoroalkyl substances and bile acids in human serum using ultra-high-performance liquid chromatography-tandem mass spectrometry." *Anal. Bioanal. Chem.* 412(10):2251-2259. doi: 10.1007/s00216-019-02263-6.

Salihovic, S; Karrman, A; Lindstrom, G; Lind, PM; Lind, L; van Bavel, B. 2013. "A rapid method for the determination of perfluoroalkyl substances including structural isomers of perfluorooctane sulfonic acid in human serum using 96-well plates and column-switching ultra-high performance liquid chromatography tandem mass spectrometry." *J. Chromatogr. A* 1305:164-170. doi: 10.1016/j.chroma.2013.07.026.

Svarcova, A; Lankova, D; Gramblicka, T; Stupak, M; Hajslova, J; Pulkrabova, J. 2019. "Integration of five groups of POPs into one multi-analyte method for human blood serum analysis: An innovative approach within biomonitoring studies." *Sci. Total Environ.* 667:701-709. doi: 10.1016/j.scitotenv.2019.02.336.

Taft Stettinius & Hollister LLP. 2020. "Plaintiff's motion for class certification [re: Kevin D. Hardwick v. 3M Co., et al.]." Submitted to US District Court, Southern District of Ohio, Eastern Division. Case No. 2:18-cv-1185. 68p., July 31.

US Dept. of Health and Human Services (US DHHS). 2017. "State Operations Manual, Appendix C - Survey Procedures and Interpretive Guidelines for Laboratories and Laboratory Services (Revision 166)." Public Health Service, Centers for Medicare & Medicaid Services (CMS), 418p., February 3.

US EPA. 2017. "Appendix B - Definition and procedure for the determination of the method detection limit - Revision 1.11." 40 CFR 136, 4p.

US Food and Drug Administration (US FDA). 1996. "Q2B Validation of Analytical Procedures: Methodology: Guidance for Industry." Center for Drug Evaluation and Research (CDER), Center for Biologics Evaluation and Research (CBER), 3p., November.

van Leeuwen, S; Strub, M; Cofino, W; Lindstrom, G; van Bavel, B. 2011. "Third interlaboratory study on perfluorinated compounds in environmental and human matrices." IVM Institute for Environmental Studies (Amsterdam, The Netherlands) Report R-11/04. 39p., May 27.

Wait, AD; Ramsey, C; Maney, J. 2015. "The measurement process." In I*ntroduction to Environmental Forensics (Third Edition)*. (Eds.: Murphy, BL; Morrison, RD), Elsevier Ltd., Oxford, England, p65-97.

Weiss, JM; van der Veen, I; de Boer, J; van Leeuwen, SPJ; Cofino, W; Crum, S. 2013. "Analytical improvements shown over four interlaboratory studies of perfluoroalkyl substances in environmental and food samples." *Trends Analyt. Chem.* 43:204-216. doi: 10.1016/j.trac.2012.10.005.

Yamashita, N; Kannan, K; Taniyasu, S; Horii, Y; Okazawa, T; Petrick, G; Gamo, T. 2004. "Analysis of perfluorinated acids at parts-per-quadrillion levels in seawater using liquid chromatography-tandem mass spectrometry." *Environ. Sci. Technol.* 38(21):5522-5528. doi: 10.1021/es0492541.

Yu, CH; Patel, B; Palencia, M; Fan, ZT. 2017. "A sensitive and accurate method for the determination of perfluoroalkyl and polyfluoroalkyl substances in human serum using a high performance liquid chromatography-online solid phase extraction-tandem mass spectrometry." *J. Chromatogr. A* 1480:1-10. doi: 10.1016/j.chroma.2016.11.063.

Zhang, Y; Beesoon, S; Zhu, L; Martin, JW. 2013. "Biomonitoring of perfluoroalkyl acids in human urine and estimates of biological half-life." *Environ. Sci. Technol.* 47(18):10619-10627. doi: 10.1021/es401905e.

Table

Table 2.1 Reported Detection Limits for Serum and Plasma – Selected Recent Studies

Reference	Sample Volume	Method	Number PFAS Analytes[a]	PFOA LOD[b] (ng/mL)	PFOA LOQ[c] (ng/mL)	PFAS LOD[b] (ng/mL)	PFAS LOQ[c] (ng/mL)
CDC (2013) (6304.04)	0.5 mL	In Serum, LOD is 3 times SD, LOQ is 5 times SD of "low-level standards." Linear range extends down to typically 0.1 times the LOD. Reported concentrations include branched and linear isomers.	12	0.1	0.2	0.08 - 0.2	0.2 - 0.7
CDC (2016) (6304.06)	50 µL	In serum, blanks calculated as less than 3 times LOD, linear range for calibration extends down to 0.01 for n-PFOA, or 0.004 for PFBS (lowest).	10	0.1	-	0.1 - 0.1	-
CDC (2018a) (6304.08)	50 µL	LOD was determined within the calibration linear range. Samples above range low point (0.07 ng/mL) but below LOD are still quantitative. Low point of range will be considered LOQ for these samples.	8	0.1	-	0.1 - 0.1	-
Lee and Mabury (2011)	2-3 mL	In serum, LOD is concentration producing S/N ≥ 3, LOQ is S/N ≥ 10. Method LOD and LOQ are reported. Instrumental LOD and LOQ are reported, but not included in this table.	36	0.002	0.005	0.001 - 0.075	0.002 - 0.113
Salihović *et al.* (2013)	150 µL	In plasma, calibration curve using 8 standard concentrations, range from 0.01 to 60 ng/mL. MDL calculated as mean concentration plus 3 times SD in serum blanks (bovine). LOQ calculated as mean concentration plus 5 times SD. Serum blanks had some PFOS, PFOA, PFDA, and PFUnDa contamination.	15	0.09	0.12	0.01 - 0.17	0.02 - 0.22
		In plasma, calibration curve using 8 standard concentrations, range of 0.01-60 ng/mL. MDL calculated as mean concentration plus 3 times SD in water blanks. LOQ calculated as mean concentration plus 5 times SD.	15	0.11	0.14	0.01 - 0.14	0.02 - 0.2
Huber and Brox (2015)	50 µL	In serum, calibration curve 0.01 to 10 pg/µL (ng/mL). MDL = 3 times SD calculated for blank. MQL was 10 times signal to noise ratio. Reporting lowest MDL as LOD, not mean MDL. PFOA contamination in water blanks and bovine serum spike.	20	0.229	-	0.003 - 0.229	-
Bartolome *et al.* (2016)	100 µL	In serum, linear ranges between 0.1 and 20 ng/mL. LOQ values for PFOS and PFHxS were increased due to contamination in blanks. Method for determining LOQ is not reported.	6	-	0.16	-	0.16 - 0.34
Pan *et al.* (2017)	200 µL	In serum, LOQ defined as lowest standard in the calibration curve with measured concentration within 70-130% of the theoretical concentrations. Reported in pg/mL, converted to ng/mL.	24	-	0.02	-	0.01 - 0.05
Poothong *et al.* (2017)	50 µL	In serum, detection limits were found by extrapolating calibration standards. MDL = S/N ≥ 3, MQL = S/N ≥ 10.	25	0.018	0.06	0.0018 - 0.09	0.006 - 0.3
		In plasma, detection limits were found by extrapolating calibration standards. MDL = S/N ≥ 3, MQL = S/N ≥ 10.		0.009	0.03	0.0018 - 0.09	0.006 - 0.3
		In whole blood, detection limits were found by extrapolating calibration standards. MDL = S/N ≥ 3, MQL = S/N ≥ 10.		0.045	0.15	0.0018 - 0.09	0.006 - 0.15
Yu *et al.* (2017)	50 µL	In serum, linear calibration range is 0.01-50 ng/mL. LOD = 3 SD, LOQ = 5 SD, established by measuring 0.01 ng/mL standard n = 7.	12	0.003	0.005	0.001 - 0.006	0.002 - 0.011
Gao *et al.* (2018)	25 µL	In serum, used a calf serum standard spiked in triplicate to build linear calibration. S/N for MLOD is 3:1. For MLOQ, S/N = 10:1	43	0.023	0.044	0.013 - 0.089	0.037 - 0.133
Gerona *et al.* (2018)	250 µL	In serum, LOD = lowest concentration of compound with S/N ≥ 3. LOQ S/N ≥ 10 and keeps linear regression with standard curve.	22	0.02	-	0.02 - 0.02	-
Honda *et al.* (2018)	250 µL	In serum, samples spiked with 50 µL standard. Linear calibration curve range is 0.01-100 ng/mL. LOD = 3 SD of lowest acceptable point, LOQ = 10 SD, n = 5.	13	0.02	0.08	0.01 - 0.03	0.02 - 0.09
Kato *et al.* (2018)	50 µL	In serum, LOD calculated as 3 times SD as concentration approaches 0. n = 5.	16	0.1	-	0.1 - 0.1	-
Poothong *et al.* (2019)	80 µL	Dried blood spots and whole blood samples. (blood spots were 50 µL). MQL were restricted to lowest calibration standard (S/N >10), MDL were set to 3/10 of the MQL. Here, MDL = LOD and MQL = LOQ.	25	0.0075	0.025	0.0075 - 0.3	0.025 - 1

Table 2.1 Reported Detection Limits for Serum and Plasma – Selected Recent Studies

Reference	Sample Volume	Method	Number PFAS Analytes[a]	PFOA LOD[b] (ng/mL)	PFOA LOQ[c] (ng/mL)	PFAS LOD[b] (ng/mL)	PFAS LOQ[c] (ng/mL)
Konopen and Kiviranta (2019)	100 µL	S/N > 10, in serum.	13	-	0.2	-	0.1 - 0.5
Reardon *et al.* (2019)	0.5 mL (= 500 µL)	In plasma, standards used 1 ng. MDL was S/N = 3:1 if blank showed no signal. For PFHpA, n-PFOS, and n-PFOA, MDL was mean concentration plus 3 times the SD of procedure blanks.	25	0.37	-	0.02 - 0.37	-
Svarcova *et al.* (2019)	3 mL (= 3,000 µL)	In human serum, MQL (LOQ) defined as S/N > 10.	19	-	0.01	-	0.01 - 0.01
Glynn *et al.* (2020)	100 µL	In serum, 3 times the SD of the blank.	15	0.2	-	0.02 - 0.2	-
Harrada, *et al.* (2020)	50 µL	In serum, 3 times the SD of n = 8 replicates.	13	0.01	-	0.01 - 0.16	-
Miaz *et al.* (2020)	0.5 mL (= 500 µL)	In pooled serum (human), calibration curve range 0.01-150 ng/mL. Lowest concentration standard with minimum peak/noise ratio over 3 and without substantial signal in blanks was used for LOQ. Where signal was observed in blanks, LOQ = Mean concentration in blanks + 3 SD. (sample specific procedure not stated). Final LOQs reported in Table S9 are recorded, units are ng/g. LOQs are converted to ng/mL using serum density = 1.025 g/mL. NOTE: Blank levels of PFOA observed during intercomparison experiment.	37	-	0.02665	-	0.0041 - 4.705
Mottaleb *et al.* (2020)	50 µl	In human serum, S/N = ~3-4 for all compounds.	8	0.04	-	0.04 - 0.2	-
Nakayama *et al.* (2020)	100 µL	In human serum, linear calibration curve range 0.04-20 ng/mL plasma (method validation used pooled plasma). MDL calculated.	28	0.11	-	0.077 - 0.16	-
Salihović *et al.* (2020)	150 µL	In plasma, calibration curve extends down to 0.02 ng/mL. 150 µL NIST standard SRM 1957 for calibration. MDL determined using mean concentration + 3 times SD. In water blanks, n = 7.	20	-	-	-	-
	20 µL			-	0.25	-	0.025 - 10

Notes:

LOD = Limit of Detection; LOQ = Limit of Quantitation; MDL = Method Detection Limit; MLOD = Method Limit of Detection; MLOQ = Method Limit of Quantitation; MQL = Method Quantitation Limit; NIST = National Institute of Standards and Technology; n-PFOA = Linear PFOA isomer; n-PFOS = Linear PFOA isomer; PFAS = Perfluorinated and Polyfluorinated Alkyl Substances; PFBS = Perfluorobutane Sulfonate; PFHpA = Perfluoroheptanoate; PFOA = Perfluorooctanoic Acid; S/N = Signal-to-Noise Ratio; SD = Standard Deviation.

(a) Branched isomers are not considered separately in this table. Value for LOD or LOQ are based on reported linear values or total values.

(b) LOD values are inclusive of values reported as LOD, MDL and MLOD.

(c) LOQ values are inclusive of values reported as LOQ, MQL and MLOQ.

Appendix A

***Curriculum Vitae* of A. Dallas Wait, Ph.D.**

A. Dallas Wait, Ph.D.
Principal
dwait@gradientcorp.com

Areas of Expertise

Environmental chemistry, consumer product chemistry, product adulterants, natural product chemistry, PCBs, PFAS, PAHs, petroleum chemistry, pesticides and herbicides, solvents, trace metals, chromatography, analytical chemistry, method and study design, quality assurance, laboratory auditing, sampling techniques and design, forensic chemistry, chemical fingerprinting, organic geochemistry, historical analytical chemistry practices, data quality, regulatory comment, and laboratory management.

Education

Ph.D., Organic Chemistry, University of Rhode Island, 1980.
American Hoechst Chemical Graduate Fellowship.

B.S., Chemistry, University of Rhode Island, 1973.

Professional Experience

1989 – Present GRADIENT, Boston, MA
Principal. Chemistry consulting practice includes evaluating the source and fate of chemicals in the environment, characterizing consumer product constituents, designing sampling and analysis methods and quality assurance programs, interpreting laboratory results, and determining the usability and integrity of data. Since 2004, my practice has expanded into the dietary supplement and food industries, resolving product adulteration, testing reliability, and structure-function health claim issues.

1986 – 1989 ENSECO – ERCO LABORATORY, Cambridge, MA
Vice President and Technical Director. Responsible for providing senior program management and analytical chemistry program design services for various commercial and government clients involved with site investigations, waste characterization, and contaminant source identification. Also involved with evaluating state-of-the-art analytical technologies for environmental analyses, such as LC/MS, isotope dilution GC/MS, and negative ion chemical ionization GC/MS.

1984 – 1985 ERCO/A DIVISION OF ENSECO, Cambridge, MA
Vice President, Director of Analytical Services, and a Co-founder of ENSECO. Responsible for the overall direction and management of organic, petroleum fingerprinting, trace metal and inorganic laboratories, overseeing 40 technical personnel. Also involved with activities associated with laboratory construction, public offerings (IPOs), laboratory acquisitions and mergers, and program management.

1978 – 1984 ENERGY RESOURCES COMPANY, INC. (ERCO), Cambridge, MA
Director of Organic Chemistry Laboratory. Managed the organic chemistry laboratory, including chromatography and GC/MS facilities used for petroleum fingerprinting, PAH, pesticide, PCB, herbicide, solvent, and specialty chemical analyses. Business areas serviced included, in part, marine oil spill research (including *Tsesis*, *Argo Merchant*, *Amoco Cadiz*, Ixtoc-I Well, and *Exxon Valdez*), agency method development studies, aquatic toxicology GLP testing support, marine drilling mud testing, alternative energy waste analysis (*e.g.*, fluidized bed combustion byproducts), consumer product characterization, and testing of wastewaters, drinking waters, site investigation samples, as well as ambient air and stack emissions.

Professional Activities

- Expert testimony evaluating the reliability of chemistry measurements and sampling procedures, characterizing consumer product constituents, assessing the source and fate of chemicals in the environment, and opining on historical analytical chemistry practices.
- Appointed member of US EPA's Science Advisory Board (a Federal Advisory Committee Act [FACA] board) involved with issues related to environmental laboratory testing (ELAB) (2012-2018). Directed work groups involved with method harmonization issues among different US EPA program offices and whole effluent toxicity (WET) testing. Deliberation topics have varied widely from cyanide testing methods to quality assurance (QA) for In-line/On-line monitoring. Appointed Vice Chair of the Board in March 2015 and Chair of the Board in March 2016.
- Member of the Ad-Hoc Industry Natural Resource Management Group (2017).
- Member of the Editorial Advisory Board for the following journals: The International Journal of Soil, Sediment and Water (2007-2010), Environmental Forensics (1999-Present), Soil and Sediment Contamination (2002-Present), Quality Assurance: Good Practice, Regulation, and Law (2004-2005), Environmental Testing & Analysis (1997-2001), and Environmental Lab (1991-1997).
- Peer reviewer for the following journals: Bulletin of Environmental Contamination and Toxicology (2017), Journal of Agricultural and Food Chemistry (2016), Journal of Association of Official Analytical Chemists (JAOAC) (2008), Environmental Health Perspectives (2006), Human & Experimental Toxicology (2006), The International Journal of Soil, Sediment and Water (2007-2010), Environmental Forensics (1999-Present), Soil and Sediment Contamination (2000-Present), and Quality Assurance (2004-2005).
- Coauthored Chapter 3, "Sampling and Analysis," in Environmental Science Deskbook: Environmental Law Series (2020)
- Member of American Herbal Products Association (AHPA) and American Society for Testing and Materials (ASTM) working groups for Cannabis (2018-Present).
- Established and directed an expert Generally Recognized as Safe (GRAS) panel evaluating the safety of caffeine in an energy drink (2010-2012).
- Member of the AHPA Sports Nutrition Committee (2010-present), AHPA Analytical Laboratory Committee (2009-Present), AHPA Pesticide Work Group (2014-present), AHPA Synthetic Ingredient Work Group (2018), as well as the Botanical Constituents Advisory Panel (2015).
- Member of the Massachusetts Department of Environmental Protection (MassDEP) Compendium of Analytical Methods Work Group (2009).
- Member of the MassDEP Massachusetts Contingency Plan (MCP) Data Usability Work Group (2006-2008).
- Participant in the Association of Official Analytical Chemists (AOAC) Presidential Task Force for Dietary Supplements (2005-2009).
- Participant in the Methods and Data Comparability Board for the National Water Quality Monitoring Council (2004-2008).
- Guest Lecturer for Harvard University Extension Environmental Management Master's Degree Program (2004-2005) and UMASS-Amherst Capstone Program (2013).
- Member of Peer Review Panel for US EPA Region II. Issues involved the conversion of Aroclor data to Tri-plus PCB data (regression analysis and test method bias) to support remediation activities in the Hudson River (2003-2004).
- Peer reviewer to "Technical Support Document for the Assessment of the Detection and Quantitation Approaches" (US EPA Office of Science and Technology, EPA-821-R-03-005) (2003).
- Invited Peer Reviewer for US EPA's Office of Water. Issues involved quantitation and detection limit concepts for regulatory analytical chemistry methods (2002).
- Presiding Organizer for the Environmental Forensic Chemistry session of the 224th American Chemical Society National Meeting – Division of Chemistry & Law (2002).
- Recipient of US EPA's FY 2001 Scientific and Technological Achievement Award (2002).
- Recipient of the National Ground Water Association (NGWA) 2001 Outstanding Ground Water Project Remediation Award at the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) – Picillo Farm Site, Coventry, Rhode Island.

- Invited Member of the Scientific Advisory Board for the AEHS International Conference on Soils, Sediments and Water (2000-Present). Also a member of the Lifetime Achievement Award Committee (2006-2012).
- Member of MassDEP MCP Data Quality Enhancement Work Group (2000-2004).
- Chairperson for Risk and Risk-based Decision Making (1999-2001), Environmental Forensics (2002, 2006, 2009-2016, 2018), Indoor Air (2005), and Chemical Analysis (2004-2005, 2009) sessions of the International Conference on Contaminated Soils, Sediments and Water, AEHS Foundation.
- Member of Test Method Coalition sponsored by Bergeson & Campbell (1998-1999).
- Member of the Massachusetts Environmental Justice Network, providing *pro bono* consultations on environmental chemistry issues affecting inner city neighborhoods (1996-Present).
- Member of ASTM Committees developing guidance and standards for environmental sampling and analysis:
  - D37.03 Cannabis-Laboratory (2018-present)
  - E50.06 Forensic Environmental Research (2005-2007)
  - D34.01.03 Wipe Sampling for Organics (2000-2001) [D6250]
  - D34.02.13 Action Level Determination (1994-1998) [D6661]
  - D34.02.04 Organic Analytical Methods (1994-1997) [various standards]
  - D34.01.12 Heterogeneous Waste Sampling (1993-1996) [D5956]
  - D34.02.10 Data Quality Objectives (1990-1991, 1993-1995) [D5792]
- Active voting member for various ASTM committees since 1990.
- Associate member of the Boston Bar Association (1997-2005).
- Member of the Greater Boston Mass Spectrometry Discussion Group (1989-1993).
- Contributing author to Resource Conservation and Recovery Act (RCRA) Test Methods for Evaluating Solid Waste – Physical/Chemical Methods, Second Edition, EPA-SW-846 (1982). Participated in the development of numerous test methods for the 1986 third edition of SW-846.
- Member of the environmental subcommittee for Princeton, Massachusetts (1989-1991).
- Occupational Safety and Health Administration (OSHA) Health and Safety Training Course (in compliance with OSHA 1910.120 regulations), including initial 40-hour course and annual refresher course (1989-2018).
- Substitute lecturer for environmental chemistry and organic chemistry classes, University of Rhode Island (1976-1978).
- Participant in the Organic Geochemistry Gordon Research Conference, Holderness, New Hampshire (August 1974, August 1976).
- Shareholder (Original Share Number 398) and member of the Redwood Library and Athenaeum in Newport, Rhode Island, the oldest continuously used community library in the United States.
- Participated in ornithological and wildlife management studies:
  - Conducted shorebird surveys at Quonochontaug, Rhode Island. Sponsored by Manomet Bird Observatory under contract with the US Department of the Interior Fish and Wildlife Service (Summers 1974-1977).
  - Conducted breeding bird surveys at Shannock and Woonsocket, Rhode Island. Sponsored by US Department of Interior Fish and Wildlife Service (Junes, 1973-1977).
  - Participant in Project Feederwatch. Sponsored by Cornell Lab of Ornithology, Ithaca, New York (Winters, 1988-2016).
  - Involved with wildlife management projects, such as deer telemetry and fish seine surveys, and bird banding projects for Canada geese, mute swans, mourning doves, wood ducks, and herons (Little Gould Island rookery). Rhode Island Fish and Wildlife Department, stationed at the Great Swamp, West Kingston, Rhode Island (Summers, 1973-1975).
  - Involved with nature studies, botany, ornithology, geology field trips, and passerine bird banding programs. Also assembled bird population field notes for publication in Audubon Field Notes, published by the National Audubon Society in collaboration with the United States Fish and Wildlife Service. Norman Bird Sanctuary, affiliate of the Rhode Island Audubon Society, Middletown, Rhode Island (Summers, 1965-1967).
  - Participant in Christmas Bird Census in Newport and/or South Kingston, Rhode Island (1965-1977).

Professional Affiliations

American Chemical Society (ACS); American Society for Testing and Materials (ASTM); Association of Official Analytical Chemists (AOAC International); American Herbal Products Association (AHPA); American Botanical Council (ABC); American Oil Chemists' Society (AOCS); International Society of Environmental Forensics (ISEF); National Groundwater Association (NGWA); Massachusetts LSP Association (Associate); American Association for the Advancement of Science (AAAS); Semiconductor Environmental Safety Health Association (SESHA)

Projects – *Environmental & Forensic Chemistry Studies*

Law Firm (Missouri): Evaluated opinions associated with the alleged disposal of hazardous substances at an Ohio Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) site landfill.

Law Firm (Texas): Evaluated fingerprinting results characterizing light non-aqueous phase liquid (LNAPL) samples associated with contamination at a natural gas plant and surrounding area.

Law Firm (New Hampshire): Evaluated the potential presence and exposure of per- and polyfluoroalkyl substances (PFAS) in paper waste sludge piles, which included designing a sampling program.

Law Firm (Massachusetts): Evaluated fingerprinting results for source identification of hydraulic fluids contaminating groundwater.

Petroleum Distributor (Massachusetts): Consulted on the source of subsurface gasoline contamination at a bulk fuel terminal.

Law Firm (New York): Consulted on the source of gasoline contamination at a commercial site in central New York State.

Cranberry Grower (Massachusetts): Conducted a forensic study to determine the identity and source of herbicides (atrazine and metolachlor) that were inadvertently applied to cranberry bogs, impacting nearly 200 acres of plants. The investigation included designing and implementing a sampling program.

Law Firm (Missouri): Consulted on the source of gasoline contamination at an Illinois site using diagnostic alkylate and additive chemistry.

Law Firm (Massachusetts): Testified on chemical fingerprints needed to delineate virgin oil from waste oil at an active commercial site. Polychlorinated biphenyl (PCB) fingerprinting was also key to the investigation.

Major Financial Institution (Massachusetts): Investigated potential sources of gasoline and diesel fuel contamination of groundwater in a commercial/residential area.

Law Firm (Pennsylvania): Evaluated sources of contamination that may have contributed to employee health complaints at a software company office building.

Jellinek, Schwartz & Connolly (Washington, DC): Consulted on structural activity and aquatic chemistry issues (biodegradation, hydrolysis, photodegradation, fugacity) in connection with US EPA's high-production-volume (HPV) chemicals program for coke ovens and tar refiners in support of the American Coke and Coal Chemicals Institute (ACCCI), and petroleum additives and aliphatic esters in support of the Chemical Manufacturers Association (CMA).

Law Firm (Texas): Testified on the composition of a petroleum hydrocarbon plume. Potential sources included gas condensates released from wellheads and pipelines, straight-run gasoline, and refined gasoline.

Jellinek, Schwartz & Connolly (Washington, DC): Consulted on various pesticide chemistry issues associated with Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) pesticide registration applications.

Law Firm (Michigan): Testified on the potential sources of chlorinated and petroleum hydrocarbon contamination in groundwater, capillary fringe, and vadose zone soil samples at a Michigan site. Potential sources of contamination included, in part, gasoline stations, a dry cleaner, and a petroleum fuel pipeline.

Engineering Firm (Massachusetts): Consulted on data interpretation issues associated with ecological risk assessments at three Massachusetts wetland sites.

Potentially Responsible Party (PRP) Group (Rhode Island): Conducted a forensic investigation to characterize a resin material uncovered at the Picillo Farm Superfund Site.

Petroleum Company (Oklahoma): Provided litigation support on the nature, extent, and source of petroleum hydrocarbon contamination at a site in Louisiana. Potential sources included a jet fuel pipeline that supplies a nearby Air Force base and a former petroleum refinery.

CBS – 60 Minutes (New York): Designed and implemented a forensic sampling and analysis program to assess lead contamination of surficial soils in urban areas in the northeastern United States.

Petroleum Company (Pennsylvania): Conducted an investigation using hydrocarbon fingerprinting and biomarkers (*e.g.*, steroids and triterpanoids) to decipher the source of a sheen on the Allegheny River.

Law Firm (Georgia): Managed a large environmental investigation in response to a multi-party toxic tort, which involved evaluating chemical partitioning and plaintiff exposure pathways from a wood-treating facility. Chemicals of concern included arsenic, zinc, copper, pentachlorophenol, and polycyclic aromatic hydrocarbons (PAHs).

Law Firm (Massachusetts): Provided expert opinions using petroleum fingerprinting to discern the source of a domestic heating fuel oil spill in southeastern Massachusetts.

S.D. Warren (Maine): Designed and implemented an analytical chemistry research program evaluating the environmental impact of applying paper pulp waste to agricultural land. The study focused on the leachability of chlorinated phenols, resin acids, fatty acids, and volatile organics from fortified soils.

Boston Edison Company (Massachusetts): Designed and implemented a sampling and analysis program to evaluate herbicide contamination of soil and vegetation in power line right-of-way areas in eastern Massachusetts. Herbicides evaluated included picloram, 2,4-dichlorophenoxyacetic acid (2,4-D), and 2-(2,4,5-trichlorophenoxy)propanoic acid (2,4,5-TP).

Power Company (Pennsylvania): Designed and implemented an analytical chemistry program using infrared fingerprinting to characterize the nature and source of foam occurring in the Susquehanna River.

University of Rhode Island: Conducted research at the Rhode Island Nuclear Science Center using neutron activation analysis to determine the trace metal content of marine organisms in the Sargasso Sea (North Atlantic Ocean).

University of Rhode Island: Conducted research using natural product fingerprinting techniques to correlate sediment outcrop strata associated with notable archeological investigations evaluating the origins of hominids. The archeological studies were conducted by Dr. Richard Leakey during the 1970s in the Lake Turkana (formerly Lake Rudolf) region of Kenya.

Projects – *Data Integrity Assessments*

Manufacturer (Minnesota): Produced an expert report for a litigation matter in Alabama involving analytical chemistry issues associated with the analysis of per- and polyfluoroalkyl substances (PFAS) in water and blood serum.

Energy Company (Tennessee): Critiqued data reliability issues associated with various site investigations at coal ash facilities.

Law Firm (California): Produced an expert report on the historical analytical chemistry testing practices for 1,2,3-trichloropropane (1,2,3-TCP) in drinking water.

Semiconductor Industry Association (SIA) (Arizona): Consulted on potential reliable test methods to measure Onium Photoacid Generators (PAGs) and their degradants in water.

Law Firm (California): Testified in a jury trial on the historical analytical chemistry testing practices for 1,2,3-trichloropropane (1,2,3-TCP) in drinking water.

Petroleum Company (Texas): Consulted on the appropriateness of disposing environmental samples collected during and after the Deepwater Horizon oil spill event that occurred in the Gulf of Mexico.

Manufacturer (Minnesota): Produced expert reports for four cases in Michigan involving analytical chemistry issues associated with the analysis of per- and polyfluoroalkyl substances (PFAS) in various matrices (*e.g.*, water, soil, air, tissue and serum).

Massachusetts Water Resource Authority (MWRA): Evaluated whether acrolein can be formed during the analysis of wastewater containing glycerol using EPA Method 603.

US Department of Justice (Washington, DC): Testified about the suitability of using the polychlorinated biphenyl (PCB) Aroclor approach (*versus* a PCB congener approach) for discerning and quantifying PCB contamination at a location in Alaska near an Air Force base.

Law Firm (Pennsylvania): Testified about the sampling and analysis approach to identifying flushable wipes in wastewater systems.

Law Firm (Pennsylvania): Testified about the sampling, analysis, and reporting practices of an environmental laboratory associated with alleged fraud claims associated with a fracking site.

Water Company (Maine): Observed a large aquifer and spring water sampling program to determine the reliability of any resultant data that may be used in litigation.

Petroleum Company (Texas): Evaluated the quality, reliability, and usability of data produced for various environmental investigations conducted in response to the Deepwater Horizon oil spill event that occurred in the Gulf of Mexico during the spring of 2010. The evaluation included a comprehensive top-down assessment of all sampling and analysis quality assurance (QA) systems. This evaluation was conducted in anticipation of Natural Resource Damage (NRD) litigation.

Law Firm (Missouri): Testified on the reliability of hexavalent chromium data for sludge samples collected and analyzed in the 1970s.

Petroleum Company (Montana): Evaluated the reliability and usability of groundwater and air measurements made in association with a crude oil pipeline spill affecting the sediments and water in the Yellowstone River.

Law Firm (Missouri): Testified on the reliability of sampling plan designs and testing results for hexavalent chromium (Cr^{+6}) in agricultural field and residential yard soils collected in areas where tannery sludge had been spread.

US Department of Justice (Washington, DC): Evaluated the appropriateness of testing practices for trichloroethylene (TCE) in drinking water during the early 1980s at a Marine Base Camp.

Law Firm (Texas): Consulted on the reliability and biases associated with 30 years of groundwater sampling practices for trichloroethylene (TCE) at a site in New York State.

US Department of Justice (Washington, DC): Testified on the reliability of sampling and liquid chromatography/tandem mass spectrometry (LC/MS/MS) analysis methods used for trace level analyses of sulfonyl urea herbicides, particularly sulfometuron methyl ("Oust"), in agricultural soils. Issues concerning Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) testing methods and data usage near or below detection limits were key.

Law Firm (Arizona): Testified on the reliability of sampling methods and chemistry data used to allege Resource Conservation and Recovery Act (RCRA) waste handling violations for diesel fuel, gasoline, and transmix at a refinery.

Magnesium Manufacturer (Utah): Testified on the reliability of sampling and analysis methods used to test for incidental polychlorinated biphenyls (PCBs), chlorinated dioxins/furans, and hexachlorobenzene in magnesium manufacturing wastes.

Law Firm (Connecticut): Consulted on the reliability and usability of polychlorinated biphenyl (PCB) data associated with remediation cost allocation, as well as sample and document spoliation issues.

Research Task Force (Ohio): Critiqued numerous chemistry studies evaluating the degradation of alkyl arsenical herbicides in soil.

Law Firm (Washington, DC): Evaluated the reliability and admissibility of arsenic measurements, including X-ray fluorescence (XRF) testing, performed on soils and groundwater at a site in Illinois.

Law Firm (Tennessee): Evaluated the applicability and integrity of two test methods used to analyze the total organic carbon (TOC) content of activated carbon wastes.

Law Firm (Missouri): Consulted on the reliability of sampling and analysis methods, as well as forensic techniques, associated with the alleged presence of the organoarsenical roxarsone in household dust.

Malcolm Pirnie (New York): Consulted with US EPA Region II and the US Army Corps about appropriate test methods for delineating polychlorinated biphenyl (PCB) "hot spots" in Upper Hudson River sediments. Subsequently, peer-reviewed regression methods proposed to convert Aroclor data to Tri-plus PCB data in support of remediation activities.

Confidential Client (Kentucky): Consulted on data integrity and data usability issues, including fraud, associated with trichloroethylene (TCE) and Technetium-99 radionuclide monitoring data supporting mixed waste remediation activities at an operational US Department of Energy facility. Subsequently provided training, method validation, and auditing services to support reopening the laboratory.

Law Firm (Washington, DC): Evaluated the usability of solvent and metals (*e.g.*, lead, cadmium, chromium, arsenic, mercury) data produced to characterize paint waste in soils as part of cost recovery litigation at the Hollis Road Site in South Carolina.

Law Firm (New York): Evaluated the potential damages associated with fraudulent practices at an environmental laboratory being considered for acquisition by a French company.

Law Firm (Louisiana): Developed and implemented a sampling and analysis program that evaluated the reliability of petroleum hydrocarbon data previously produced to support litigation associated with pipeline crude oil contamination.

Law Firm (Massachusetts): Testified on the quality, usability, and interpretation of data used to assess the source of historical fuel oil spills at an operating frozen food manufacturing facility. This was the first jury trial held under the Massachusetts Superfund statute.

Law Firm (California): Evaluated the integrity, usability, and interpretation of methyl tert-butyl ether (MTBE) data obtained as part of an investigation of a Los Angeles aquifer.

Law Firm (Illinois): Testified on benzene measurement and representative sampling issues associated with testing petroleum refinery process wastewaters regulated under the National Emission Standards for Hazardous Air Pollutants (NESHAP; 40 CFR Part 61, Subpart FF). Issues concerning fraudulent laboratory activities were significant.

Law Firm (Massachusetts): Evaluated the quality, usability, and interpretation of fingerprinting data used to assess the source of historical petroleum spills at a bulk fuel terminal in support of insurance coverage claims.

Railroad (Delaware): Consulted on the applicability and implementation of polychlorinated biphenyl (PCB) congener methods, including isotope dilution Method 1668, used to support a National Pollutant Discharge Elimination System (NPDES) wastewater discharge permit.

Law Firm (Massachusetts): Testified on the interpretation and usability of polycyclic aromatic hydrocarbon (PAH), volatile organic, petroleum hydrocarbon fingerprinting, and carbon isotope dating data used to discern potential sources of creosote, pine tar, and petroleum constituents in soils at a site in Florida.

Petroleum Company (Oklahoma): Provided litigation support regarding the usability of indoor air data produced using TO-14 summa canisters in a residential area located atop a former petroleum refinery in northwest Louisiana. Participated in numerous negotiation sessions with US EPA Region VI regarding appropriate sampling and analysis methods for ambient air.

US Department of Justice (Washington, DC): Provided litigation support regarding the integrity of laboratory data produced in support of an National Pollutant Discharge Elimination System (NPDES) wastewater discharge permit for a petroleum refinery in California.

Law Firm (Texas): Provided litigation support assessing the usability of fingerprinting data produced to differentiate incinerator sources of dioxin/furans (PCDD/Fs) in surface soils.

Law Firm (California): Provided litigation support evaluating the potential presence of methyl tert-butyl ether (MTBE) in Los Angeles-area groundwater and soils contaminated with gasoline.

Law Firm (Arizona): Testified on testing and sampling practices for trihalomethanes (THMs) and trichloroethylene (TCE) in drinking water, which municipalities should have been implementing during the early 1980s.

Petroleum Company (Oklahoma): Established and oversaw a sampling and analytical chemistry program to evaluate potential groundwater contamination from gasoline stations located in six states (Wisconsin, Illinois, Indiana, Florida, Pennsylvania, and Massachusetts). Testing included methyl tert-butyl ether (MTBE), ethylene dibromide/ethylene dichloride (EDB/EDC), and benzene, toluene, ethylbenzene and xylene (BTEX) surveys, and petroleum hydrocarbon fingerprinting. Also provided testimony about the reliability of data used to allocate contaminant liability.

Law Firms (Pennsylvania, New York): Testified on the analytical chemistry capabilities of laboratories to analyze for trichloroethylene (TCE) and trichloroethane (TCA) in groundwater and surface waters in the late 1960s.

Law Firm (California): Testified on data quality issues associated mainly with polychlorinated biphenyl (PCB) analyses for numerous site investigations at an operating manufacturing facility, and subsequently designed a new sampling and analysis program. Other chemicals of concern included petroleum hydrocarbons, solvents, and metals (*e.g.*, lead). Also provided opinions regarding the identification of PCBs (congener fingerprinting) for source allocation and designed wipe sampling procedures for porous surfaces to evaluate dermal uptake of PCBs. Participated in negotiations with California Department of Toxic Substances Control (CalDTSC) regarding data assessment and sampling strategies.

Law Firm (New York): Assessed the integrity of a sampling and analysis program designed to locate sources of lead contamination in the drinking water system of a New York school campus.

Law Firm (Connecticut): Assessed data quality issues associated with leachate testing at the Beacon Heights Landfill CERCLA site in support of a tire manufacturer (Pirelli-Armstrong Rubber) involved with contaminant liability litigation.

Law Firm (Michigan): Testified on the reliability of groundwater carbon tetrachloride data used at a site investigated by the Michigan Department of Natural Resources (DNR).

Petroleum Company (New Jersey): Participated in negotiations with New Jersey Department of Environmental Protection (NJDEP) regarding the usability of data relative to strict data validation findings.

Law Firm (Washington, DC): Testified in numerous toxic torts about the integrity of the analytical chemistry and sampling procedures used to test for the pesticide chlordane in residential settings.

Law Firm (New York): Provided litigation support regarding historical analytical chemistry practices used to monitor groundwater quality at an operating New Jersey chemical company.

Mining Company (Colorado): Assessed sampling procedures, data quality and integrity, document control systems, and laboratory testing performance for site-specific chemicals and radionuclides for the purpose of source identification and remediation in anticipation of litigation.

Hazardous Waste Company (Ohio): Critiqued a Resource Conservation and Recovery Act (RCRA) Corrective Action Plan pertaining to data validity and usability, database management, and risk assessment issues.

Law Firm (Pennsylvania): Provided litigation support to a pipeline company to assess the quality and usability of polychlorinated biphenyl (PCB) data associated with numerous site investigations.

Projects – *Data Quality Management*

Paper Mill (New Hampshire): Designed and oversaw a sampling and analysis program to evaluate whether per- and polyfluoroalkyl substances (PFAS) were present in paper waste sludge.

Water-treatment Facility (West Virginia): Developed a sampling plan for granulated activated carbon (GAC) filter beds at a water-treatment facility in anticipation of litigation for possible violations under the Clear Water Act (CWA).

Laundry Company (Connecticut): Designed a sampling and analysis program to investigate the possible presence of nonylphenol and nonylphenol ethoxylates in laundry wastewater.

Petroleum Refinery (Illinois): Established a laboratory contract program supporting benzene testing of process wastewaters for National Emission Standards for Hazardous Air Pollutants (NESHAP) regulatory compliance.

Arthur D. Little (Massachusetts): Managed a laboratory audit and performance evaluation program in support of the US Army Assembled Chemical Weapons Assessment program at the Aberdeen Proving Ground in Maryland.

Petroleum Company (Louisiana): Designed and oversaw an analytical chemistry program focused on polycyclic aromatic hydrocarbons (PAHs) for a Resource Conservation and Recovery Act (RCRA) closure of a 26-acre petroleum refinery sludge holding pond.

Petroleum Company (California): Established and oversaw a national laboratory contract program during the mid-1990s, supporting site investigations nationwide.

Potentially Responsible Party (PRP) Group (Rhode Island): Provided quality assurance (QA) oversight services for monitoring and remediation activities at the Picillo Farm Superfund Site in Coventry, Rhode Island. Groundwater contaminants of concern were mostly solvents, including 1,4-dioxane. One project involved "clean-hands" wastewater sampling and analysis for zinc and aluminum. Another project involved stack emissions analysis associated with a groundwater remediation facility. Negotiated with US EPA Region I regarding testing protocols and data assessment procedures.

Petroleum Company (Oklahoma): Established and oversaw a national laboratory contract program during the early to mid-1990s, supporting site investigations nationwide.

Raymark Industries (Connecticut): Provided quality assurance (QA) oversight for a Resource Conservation and Recovery Act (RCRA) facility investigation (RFI) at a former brake manufacturing facility contaminated with asbestos, lead, polychlorinated biphenyls (PCBs), solvents, and dioxin/furans (PCDD/Fs). Participated in numerous negotiation sessions with US EPA Region I regarding analytical method design, data assessment, and interpreting data usability for human health risk assessments.

TAMS Engineering (New York): Designed and oversaw a polychlorinated biphenyl (PCB) congener analytical chemistry and sampling program to reassess the distribution of PCBs throughout a 200-mile stretch of the Hudson River ecosystem. Over 3,000 river water, sediment, particulate, and biota samples were analyzed. Participated in negotiations with US EPA Region II for approval of a unique PCB congener test method and data validation protocols.

Midwest Gas Company (Michigan): Evaluated laboratory performance associated with remedial investigations at manufactured gas plant (MGP) sites.

Petroleum Company (Louisiana): Designed and oversaw an analytical chemistry program as part of an remedial investigation/feasibility study (RI/FS) at a former petroleum refinery site located in northwest Louisiana. The study included, in part, an extensive indoor air screening program using method TO-14 at numerous apartment complexes. Participated in numerous negotiation sessions with the Louisiana Department of Environmental Quality (LADEQ) and US EPA Region VI regarding appropriate sampling and analysis methods.

Chemical Company (New York): Provided quality assurance (QA) oversight services for a remedial investigation/feasibility study (RI/FS) being conducted at an inactive chloralkali manufacturing facility. Contaminants of concern included mercury, polychlorinated biphenyls (PCBs), and solvents. The sampling and analysis program for mercury entailed low-level mercury and methyl mercury determinations using "clean-hands" sampling techniques.

Utility (New York): Performed confidential due diligence and auditing at 11 laboratories nationwide in consideration of a utility acquiring environmental laboratory businesses.

Anitec-International Paper (New York): Provided quality assurance (QA) oversight for a remedial investigation (RI) at an active photographic material manufacturing facility. Chemicals of concern included polycyclic aromatic hydrocarbons (PAHs), solvents, polychlorinated biphenyls (PCBs), and metals. Participated in numerous negotiation sessions with the New York State Department of Environmental Conservation (NYSDEC) and New York State Department of Health regarding analytical methods, background measurements, and viable exposure pathways.

Petroleum Company (Louisiana): Conducted a series of Louisiana-based laboratory audits evaluating their ability to provide analytical services for site investigation and monitoring programs at a Lake Charles refinery.

Utility (New York): Evaluated business strategies for a utility to acquire a commercial environmental laboratory business.

Argonne National Laboratory (Illinois): Provided quality assurance (QA) oversight for a remedial investigation at Air Force Plant 59 in Johnson City, New York. Test methods included field X-ray fluorescence (XRF) analysis for certain trace metals (*e.g.*, lead, chromium, cadmium). Negotiated with New York State Department of Environmental Conservation (NYSDEC) Region 7 on behalf of the Air Force regarding chemicals of concern, detection limits, and analytical methods.

Confidential Environmental Laboratory (New York): Provided consulting management services to upgrade operational and technical systems to meet New York State Department of Environmental Conservation (NYSDEC) requirements for environmental testing laboratories.

Stetson-Harza (New York): Provided quality assurance oversight for field sampling and chemistry services required as part of a remedial investigation/feasibility study (RI/FS) program at a landfill in Whitestown, New York. Supplemental court testimony successfully demonstrated that reliable data quality was produced.

Metcalf & Eddy (New York): Provided quality assurance (QA) services for numerous site investigations at inactive hazardous waste sites in New York, including corrective action for work previously conducted by other contractors. Negotiated directly with the New York State Department of Environmental Conservation (NYSDEC) regarding the usability of data previously generated at some of the waste sites.

Exxon (Alaska): Designed an analytical chemistry program and oversaw analyses of sediment, water, and swab samples collected in Prince William Sound following the *Exxon Valdez* oil spill. The program evaluated sources of petroleum hydrocarbons in the sound, evaluated the progress of the oil spill cleanup, and evaluated ecological impacts.

Projects – *Regulatory Comment*

US EPA Office of Water (Washington, DC): Peer-reviewed documents detailing detection limit and quantitation concepts for regulatory analytical chemistry methods in response to a settlement agreement between various trade associations and US EPA (Alliance of Automobile Manufacturers *et al. v.* EPA, DC Cir. No. 99-1420, 10/19/00). The results are reported in "Technical Support Documents for the Assessment of Detection and Quantitation Approaches" (EPA-821-R-03-005, February 2003).

Law Firm (California): Testified on perchlorate regulatory chemistry and Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) classification issues associated with a drinking water aquifer in southern California.

UniFirst Corporation (Massachusetts): Provided comments to US EPA regarding the reliability of data used to derive proposed pretreatment phthalate standards for the industrial laundries point source category (40 CFR Part 441).

Consulting Firm (Washington, DC): Evaluated the quality of data used by US EPA to derive pretreatment standards for the industrial laundries point source category. This work was supported by the Uniform and Textile Services Association (UTSA) and the Textile Rental Services Association (TRSA).

Law Firm (Georgia): Provided an expert report critiquing a piezobalance method for analyzing respirable air particulates detailed in a proposed Occupational Safety and Health Administration (OSHA) regulation for indoor air.

US EPA Office of Solid Waste (Washington, DC): Co-authored the gas chromatography (GC), gas chromatography/mass spectrometry (GC/MS), and sample preparation methods published in the 1982 second edition of SW-846, titled "Test Methods for Evaluating Solid Waste," and participated in the development of numerous test methods for the 1986 third edition of SW-846. For over three decades, this manual has been the basis for the Resource Conservation and Recovery Act (RCRA) testing program.

Projects – *Method Development/Assessment Programs*

Confidential Utility (Northeast United States): Designed a sampling and analysis study, using, in part, Fourier-transform infrared spectroscopy (FTIR), to evaluate the nature of gas and chemical emissions produced from faulting events of underground power transmission lines encased in coal tar insulation.

US EPA Office of Research and Development (Ohio): Participated in a multi-laboratory study to evaluate the reliability of a gas chromatography/mass spectrometry (GC/MS) method for the analysis of polychlorinated biphenyl (PCB) homologues and pesticides (Method 680).

Chemical Company (Ohio): Designed negative ion chemical ionization mass spectrometry isotope dilution methods for ultra-low-level analyses of the pesticides mirex and kepone in groundwater, soil, sediment, air (XAD-2), and tissue samples. Negotiated extensively with US EPA Region V prior to method approval.

US EPA Quality Assurance Branch (Ohio): Managed a task order contract to validate six Safe Drinking Water Act (SDWA) analytical chemistry methods under consideration for trace-level analysis of organics in drinking water. Methods evaluated include Method 502.2 (volatile organics by GC/PID), Method 531.1 (N-methyl carbamoyl oximes by HPLC), Method 505 (organohalide pesticides by microextraction GC/ECD), Method 524.2 (purgeable organics by GC/MS), Method 515.1 (chlorinated acids by GC/ECD), and Method 504 (bromo/chloro volatile organics by microextraction GC/ECD).

US EPA Office of Solid Waste (Washington, DC): Managed Resource Conservation and Recovery Act (RCRA) task order assignments associated with the development/evaluation of analytical methods used to detect the presence of hazardous waste constituents and classify wastes. Several tasks included developing clean-up procedures for analyzing petroleum refinery wastes, developing extraction procedure (EP) and toxicity characteristic leaching procedure (TCLP) extraction procedures, conducting a nationwide waste oil characterization study, analyzing polycyclic aromatic hydrocarbons (PAHs) in coke wastes, characterizing paint wastes and petroleum refinery wastes (*e.g.*, oil/water separator emulsions, rag oils, still bottoms, slop oils) for delisting petitions, and characterizing the metal content of coal ash.

Photographic Manufacturer (Massachusetts): Developed and oversaw a specialized gas chromatography (GC) monitoring program for polar organic solvents in various process waste streams.

University of Rhode Island: Established a training program for university science departments to manufacture glass capillary gas chromatography (GC) columns for analytical chemistry research. The technology was developed under a tutelage program at the Organic Geochemistry Unit of the University of Bristol, England, headed by Dr. Geoffrey Eglinton.

Projects – *Dietary Supplement/Food Chemistry Studies*

Dietary Supplement Manufacturer (New York): Consulted on possible health effects from Haloxyfop, a selective herbicide, in a Chia-Flax supplement.

Insurance Company (Colorado): Consulted on an insurance claim in which the insured asserted that two fire incidents resulted in the loss of proprietary cannabidiol (CBD) legal processing, extraction, and distilling R&D records.

Dietary Supplement Manufacturer (Michigan): Opined on the use of a cobalt ICP/MS test method to measure vitamin B12 in a dietary supplement.

Law Firm (California): Testified on the reliability of testing results alleging the identification of diethylphenethylamine compounds in a *Dendrobium*-based pre-workout dietary supplement.

Food Manufacturer (Ontario, Canada): Evaluated the extent and potential human health risks associated with the accidental contamination of a coffee product with triethylene glycol.

Dietary Supplement Manufacturer (Michigan): Testified in numerous affidavits about measurement representativeness and variance needed to characterize a chemical constituent in a supplement product.

Law Firm (New York): Evaluated the reliability of testing results alleging the presence of amphetamine-type compounds in various dietary supplements.

Filter Manufacturer (California): Consulted on a food contact migration study to support the commercial use of a reusable filter cartridge for processing drinking water and alcoholic beverages. The study indicated that potential dietary exposure to two non-sanctioned food contact substances (FCS) were below FDA's Threshold of Regulation (TOR).

Law Firm (Washington, DC): Directed an evaluation of telomere stability, oxidative stress, and anti-oxidative properties associated with a botanical supplement product. Telomeres are repeating nucleoprotein caps on the end of chromosomes.

Dietary Supplement Manufacturer (Michigan): Designed and oversaw a testing program for glucoronolactone in various food and produce products.

Law Firm (Washington, DC): Designed and oversaw a testing program for CDP-choline in various food and produce products.

Law Firm (Missouri): Consulted on the safety of a miticide, tau-fluvalinate, detected in some dietary supplements in which beeswax was used as an emulsifier.

Dietary Supplement Manufacturer (Texas): Testified about the reliability of data alleging the presence of clenbuterol in two dietary supplements. The investigation involved an Olympic swimming contender.

Law Firm (Washington, DC): Established and directed a Generally Recognized as Safe (GRAS) self-affirmation expert panel evaluating the safety of an ingredient in two energy shot products.

Dietary Supplement Manufacturer (Arizona): Consulted on New Dietary Ingredient (NDI) issues associated with various ingredients proposed to be added to energy and weight-loss supplement products.

Law Firm (Washington, DC): Conducted a gap analysis for safety information pertaining to a human growth hormone, in anticipation of an New Dietary Ingredient (NDI) notification to the US Food and Drug Administration (FDA).

Dietary Supplement Manufacturer (Texas): Evaluated the lead content of various botanical dietary supplements relative to natural background in a California Proposition 65 matter.

Law Firm (Washington, DC): Conducted a trend analysis for adverse event reports (AERs) filed with the US Food and Drug Administration (FDA) for four dietary supplement products.

Dietary Supplement Manufacturer (Vermont): Designed and implemented a state-of-the-art arsenic speciation testing program for an omega-3 fish oil dietary supplement product. The results were used to evaluate possible human health risks.

Pet Food Manufacturer (South Carolina): Testified on the reliability of data alleging the presence of diethylene glycol (DEG) in dog treats.

Dietary Supplement Manufacturer (Nevada): Consulted on New Dietary Ingredient (NDI), Good Manufacturing Practice (GMP), and structure-function claim issues supporting potential sales of a new phytoplankton supplement in the US market.

Law Firm (Washington, DC): Consulted on phytosterol health claims for a dietary supplement.

Dietary Supplement Manufacturer (Arizona): Consulted on California Proposition 65 regulations relative to possible health effects associated with inorganic arsenic found in various supplement products.

Law Firm (California): Consulted on the usage, regulatory status, and chemistry of *Hoodia gordonii*, a weight-loss product ingredient.

Law Firm (Washington, DC): Conducted a gap analysis for safety information associated with zeaxanthin (a carotenoid alcohol), as a macular pigment, in anticipation of a New Dietary Ingredient (NDI) notification to the US Food and Drug Administration (FDA).

Law Firm (Wisconsin): Investigated possible whey adulteration by an ethanol manufacturing plant proposed to be constructed adjacent to a supplement manufacturing facility.

Cranberry Grower (Massachusetts): Conducted a forensic study to determine the identity and source of herbicides (atrazine and metolachlor) that were inadvertently applied to cranberry bogs, impacting nearly 200 acres of plants.

Law Firm (Rhode Island): Conducted a forensic investigation into the presence and source of anabolic steroids in a whey-based dietary supplement. The investigation involved two separate plaintiffs: an NFL football player and a Winter Olympics athlete.

Dietary Supplement Manufacturer (Vermont): Oversaw the development of substantiation files addressing structure-function health claims for numerous supplement ingredients.

Dietary Supplement Manufacturer (Florida): Oversaw an assessment of published papers that examined the relationship of dietary supplements such as vitamins, minerals, and natural products (*e.g.*, mushrooms) to structure-function claims.

US Department of Justice (Washington, DC): Consulted on the design of a storage stability study for malathion and malaoxon pesticides collected on air filters and alpha cellulose receptors associated with spray drift studies at a tropical fruit farm in Puerto Rico.

Major Newspaper (Massachusetts): Conducted a study to determine the polychlorinated biphenyl (PCB) content of marketplace bluefish.

Juice Manufacturer (Massachusetts): Conducted a testing program to characterize apple pulp waste.

UMASS Experiment Station (Massachusetts): Conducted a study to determine the organophosphorus pesticide content of various cranberry foodstuffs.

Projects – *Product/Technology Assessments*

Biofuel Manufacturer (South Dakota): Consulted on the safety of using bio-based ethanol in hand sanitizers.

Confidential Manufacturer (Canada): Assessed the appropriateness of a ^{19}F NMR method used to measure and characterize the fluorine content of various solutions prepared for a skin contact study.

Biofuels Trade Organization (Washington, DC): Consulted on the preparation of a Tier I E15 Multimedia Evaluation report for submission to the California Air Resources Board (CARB) for approval of a 15% ethanol gasoline product.

Law Firm (New York): Consulted on potential chemical contaminants in water that may cause degradation of chlorinated polyvinyl chloride (CPVC) piping in high-rise buildings.

Law Firm (California): Critiqued a testing program measuring bisphenol A (BPA) in baby teethers.

Chemical Company (New York): Testified about the chemical reactivity of α-ketones and β-ketones with a specific focus on the reaction chemistry of 2,4-pentanedione (a β-ketone) as it compares to 2,3-pentanedione and 2,3-butanedione (diacetyl) (α-ketones).

Flooring Manufacturer (California): Testified about the reliability and appropriateness of testing conducted to assess formaldehyde emissions from composite wood products.

Cork Manufacturer (France): Assessed the analytical methodology used to evaluate the migration of toluene diisocyanate (TDI) and its degradates from agglomerated cork stoppers into bottled wine.

Railroad Company (Nebraska): Testified about alleged chronic exposure to crystalline silica during the handling of silicon metal on railroad cars. The oxidation of silicon metal and the chemistry of silicon dioxide were key to the investigation.

United Soybean Board (Missouri): Evaluated possible data quality issues associated with the aquatic toxicity testing of a biofuel to comply with US EPA's Design for the Environment Safer Product Labeling Program.

Law Firm (California): Testified about the reliability of differing test results characterizing the purity of the pesticide product Acephate.

Law Firm (Rhode Island): Evaluated whether mixing a floor adhesive with a cleaning solvent could produce hydrogen cyanide gas and determined potential inhalation exposure to methylene diphenyl diisocyanate (MDI).

Defense Advanced Research Projects Agency (DARPA) (Virginia): Designed and implemented test methods supporting the development of technology to collect atmospheric trace constituents for chemically mapping urban and military environments.

Law Firm (Pennsylvania): Developed and oversaw an ion chromatography/tandem mass spectrometry (IC/MS/MS) testing program to determine the presence of perchlorate in various fertilizer products.

Engineering Firm (Tennessee): Consulted on reaction chemistry issues associated with the waste treatment of lithium hydride that resulted in a fire incident.

Law Firm (California): Consulted on the development of a test method to determine the presence of perchlorate in a confidential consumer product.

Law Firm (Massachusetts): Provided litigation support in a toxic tort evaluating the presence of a fungicide (chlorothalonil) in a sealant product.

Law Firm (Washington, DC): Evaluated the applicability and implementation of NSF extraction procedures used to determine the leachability of lead from faucet systems regulated under California Proposition 65.

Law Firm (Michigan): Critiqued arbitration expert reports involving the allocation of liability for contamination associated with antioxidant product tolling (specialty chemical manufacturing) and solvent reclamation facilities sited on a former petroleum refinery.

Law Firm (Washington, DC): Provided litigation support evaluating the chemistry of raw materials, intermediates, byproducts, and final products associated with waste generated in manufacturing the pesticide chlordane.

Potentially Responsible Party (PRP) Group (Michigan): Developed an analytical chemistry program and oversaw soil flushing experiments designed to evaluate remediation alternatives at the Demode Road Superfund Site in Rose Township, Michigan.

Industrial Economics, Inc. (Massachusetts): Proposed test methods to analyze for volatile organic compounds in consumer products, particularly aerosol canisters. This project supported US EPA studies designed to evaluate strategies to reduce tropospheric ozone levels.

Arthur D. Little, Inc. (Massachusetts): Conducted analytical chemistry programs designed to evaluate supercritical fluid extraction procedures for various materials ranging from potato chips to hazardous waste.

Erving Paper Mills (Massachusetts): Designed and conducted a sampling and analysis program to determine the polychlorinated biphenyl (PCB) content of various paper products and manufacturing intermediates.

Pennzoil Products Company (Texas): Oversaw a testing program during the mid-1980s to determine the polycyclic aromatic hydrocarbon (PAH) content of various motor oil products.

US Printing Ink (New Jersey): Oversaw a testing program during the mid-1980s to determine the polycyclic aromatic hydrocarbon (PAH) content of various printing ink manufacturing intermediates.

Manufacturer (Massachusetts): Oversaw a testing program during the early 1980s to determine the polycyclic aromatic hydrocarbon (PAH) content of carbon black and manufacturing intermediates.

US EPA Industrial Environmental Research Laboratory (North Carolina): Managed an analytical chemistry program designed to characterize aqueous, atmospheric, and solid effluents generated from the combustion of various types of refuse-derived fuels.

Power Recovery Systems, Inc. (Massachusetts): Managed an analytical chemistry program designed to evaluate environmental contamination associated with fluidized-bed combustion technology. Compounds of interest included pyrogenic polycyclic aromatic hydrocarbons (PAHs), PAH oxygenates, phenolics, and heterocycles.

Remediation Technologies, Inc. (Massachusetts): Managed an analytical chemistry program evaluating the presence of chlorinated dioxins/furans (PCDD/Fs), polycyclic aromatic hydrocarbons (PAHs), and pentachlorophenol generated by the incineration of creosote-contaminated soils collected from railroad facilities.

Tnemec (Missouri): Conducted leachate studies of coating materials used in water storage tank linings to assess the potential for solvent contamination of stored water.

New York State Department of Environmental Conservation (NYSDEC): Oversaw an analytical testing program evaluating the effectiveness of remedial technologies being considered for the destruction of Love Canal wastes.

Bradford Soap Works (Rhode Island): Investigated rancid soap problems (anomalous fatty acid content) associated with raw materials used to manufacture soaps.

Projects – *Environmental Testing Programs*

US EPA Effluent Guidelines Division (Washington, DC): Managed analytical chemistry service contracts designed to characterize priority pollutants in industrial wastewater. Managed another contract that used isotope dilution gas chromatography/mass spectrometry (GC/MS) techniques for the analysis of organics in industrial wastewater samples.

US EPA Contract Laboratory Program (CLP) (Washington, DC): Managed a series of analytical chemistry service contracts (for over 8 years, representing over $2.6 million in revenue) in support of organic analytical services required for Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Superfund site investigations.

US EPA Health Effects Research Laboratory (Ohio): Managed an extensive chemistry program analyzing purgeable organics in drinking water. Analyzed samples in support of an epidemiological study correlating the presence of organic solvents in drinking water with increased incidence of certain types of cancer.

Drilling Mud Manufacturers and Petroleum Companies (US, Nationwide): Oversaw chemical testing for heavy metals and biocides to support aquatic toxicity studies of various marine drilling muds.

US EPA Region I (Massachusetts): Managed task order assignments (10 years) requiring analysis of environmental site and industrial waste samples for hazardous compounds.

US EPA Office of Water Regulations and Standards (Massachusetts): Managed an analytical chemistry program as part of the National Urban Runoff Program (NURP). In conjunction with the Massachusetts Department of Environmental Quality Engineering (DEQE), performed analyses for organic and trace metal priority pollutants in stormwater runoff from Lake Quinsigamond and the Mystic River Watershed.

New York State Electric & Gas (New York): Managed a series of analytical chemistry programs evaluating soil contamination at manufactured gas plant (MGP) sites throughout New York.

Union Camp (New Jersey): Managed numerous analytical chemistry programs in support of National Pollutant Discharge Elimination System (NPDES) and site investigation programs for pulp and paper operations nationwide. Assisted in negotiations with the State of Virginia regarding Union Camp's wastewater disposal permit at its Franklin facility.

Numerous Chemical Companies: Managed Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) Good Laboratory Practice (GLP) testing programs supporting aquatic toxicology studies.

Real Estate Developer (Rhode Island): Oversaw an analytical chemistry program designed to characterize sediments at a former manufactured gas plant (MGP) site in Newport, Rhode Island. This site was the first location in the United States that used manufactured gas (*circa* 1806).

Allied Chemical (New Jersey): Managed an analytical chemistry monitoring program in support of a multi-year ocean dumping permit in areas off the northeastern coast of the United States.

Numerous Municipalities (Northeast United States): Managed various analytical chemistry programs associated with drinking water supply wells regulated under the Safe Drinking Water Act (SDWA).

Numerous Industries (US, Nationwide): Managed analytical chemistry programs required for National Pollutant Discharge Elimination System (NPDES) permit applications. Also managed numerous aquatic toxicology chemistry programs conducted in accordance with Good Laboratory Practice (GLP) requirements. In addition, managed projects involved with emergency spill response, waste disposal, and property acquisitions and transfers.

Numerous Engineering Firms (US, Nationwide): Managed projects requiring chemistry measurements for characterizing sites, determining contaminant liability, and monitoring closure activities.

New York State Department of Environmental Conservation (NYSDEC): Managed a series of contracts (for 10 years, representing over $1.8 million in revenue) providing analytical services in support of remedial investigations, environmental enforcement, wastewater permitting, waste characterization (*e.g.*, paints, oils, solvents), and municipal sludge land spreading studies. In addition, provided expert testimony in support of the analytical chemistry work performed under these contracts.

New York State Department of Law (NYSDOL): Managed a series of analytical chemistry service contracts for contaminant characterization of environmental and industrial waste samples.

Woods Hole Oceanographic Institution (Massachusetts): As a participant in the Mussel Watch Program, conducted petroleum hydrocarbon analyses (aliphatics, pristane, phytane, polycyclic aromatic hydrocarbons [PAHs]) of *Mytilus edulis* tissue samples. The program was designed as an intercomparison study of testing methods for petroleum hydrocarbons in the marine environment.

US Bureau of Land Management (Washington, DC): As a Principal Investigator, managed an analytical chemistry program encompassing petroleum hydrocarbon fingerprinting and polycyclic aromatic hydrocarbon (PAH) distribution analysis to assess the ecological effects and fate of the Ixtoc oil spill in the marine environment of the Gulf of Mexico.

US Geological Survey (USGS) Water Resource Division (Colorado): Managed a 3-year contract providing analysis of organic compounds (volatile organics, semivolatile organics, and organochlorine and organophosphorus pesticides) in groundwater. The results were used to investigate the quality of the nation's water resources during the mid-1980s.

National Oceanic and Atmospheric Administration (NOAA) (Washington, DC): Directed an analytical chemistry program using petroleum hydrocarbon fingerprinting and polycyclic aromatic hydrocarbon (PAH) distribution analyses to assess the ecological effects of the *Amoco Cadiz* oil spill off the coast of Brittany, France.

US Bureau of Land Management (Washington, DC): Directed a testing program associated with establishing a petroleum hydrocarbon inventory for George's Bank ocean sediments off the northeastern coast of the United States. The research was conducted in anticipation of off-shore petroleum exploration drilling activities.

State of Maine Department of Environmental Protection: Managed task order assignments for analytical services required in support of hazardous waste investigations.

Publications

Wait, AD; Tuit, CB; Maney, JP. 2020. "Forensic sampling practices for oil spills in the marine environment." *Environ. Forensics* doi: 10.1080/15275922.2020.1806949.

Noble, AE; Tuit, CB; Maney, JP; Wait, AD. 2020. "A review of marine water sampling methods for trace metals." *Environ. Forensics* doi: 10.1080/15275922.2020.1771629.

Tuit, CB; Wait, AD. 2020. "A review of marine sediment sampling methods." *Environ. Forensics* doi: 10.1080/15275922.2020.1771630.

Tuit, CB; Wait, AD. 2020. "Sampling and Analysis." Chapter 3, in *Environmental Science Deskbook: Environmental Law Series*. (Ed: Conrad, JW), Thomson Reuters, Eagan, Minnesota.

Wait, AD; Verslycke, T. 2019. "Uniform Data Quality Ecotoxicity Assessment." In *Natural Resource Damages – A Guide to Litigating and Resolving NRD Cases*. (Eds.: Israel, BD; Marston, B; Daniel, L.), American Bar Association (ABA), Washington, DC, p213-215.

Rice, J; Lewandowski, T; Wait, AD. 2019. "Safety of cannabis-infused edibles remains hazy." *Trends – Risk Science and Applications* 75:3-5.

Wait, AD. 2018. "Data quality challenges posed by citizen science." *Trends – Risk Science and Applications* 73:3.

Verslycke, TA; Wait, AD. 2017. "Data quality in natural resource and environmental damage litigation." *Natural Resources & Environments* 31(4):15-19.

Wait, AD. 2017. "Marine oil spill data quality." *Trends – Risk Science and Applications* 68:3.

Wait, AD; Ramsey, C; Maney, J. 2015. "The measurement process." In *Introduction to Environmental Forensics, Third Edition.* (Eds.: Murphy, BL; Morrison, RD), Elsevier, Oxford, United Kingdom, p65-97.

Wait, AD. 2014. "The importance of reliable product chemistry data: A case study." AHPA Report, American Herbal Products Association, October.

Wait, AD; Reid, KR. 2012. "Defenseless without defensible data." *For the Defense* 54(1):78-83,88.

Wait, AD. 2010. "Data quality and transparency in the dietary supplement industry." *Food Drug Law J.* 65:471-487.

Wait, AD; Reid, KR; Occhialini, J; Todaro, J. 2010. "Time travel, fabrication, manipulation, and spoliation – Threats to data quality." *Environ. Claims J.* 22:171-183.

Lewis, AS; Beyer, LA; Langlois, CJ; Yu, CJ; Wait, AD. 2008. "Considerations in toxicology study design and interpretation: An overview." *Inside Aloe Online – The Official Publication of the IASC* August 15.

Wait, AD. 2008. "Data quality: Why you should assume nothing." *Windjammer Currents* September 1:3.

Wait, AD; Ramsey, C. 2007. "The measurement process." In *Introduction to Environmental Forensics, Second Edition.* (Eds.: Murphy, BL; Morrison, RD), Academic Press, Burlington, MA, p83-128.

Wait, AD. 2007. "An environmental overview of alkylphenol ethoxylates." In *Proceedings of the 2007 NGWA Ground Water and Environmental Law Conference*, Dublin, OH, July 24-25.

Wait, AD; Maney, JP. 2006. "Regulatory science and the Data Quality Act." *Environ. Claims J.* 18:145-162.

Wait, AD. 2006. "Limitations of test methods." *Trends – Risk Science and Applications* 35:4.

Wait, AD. 2005. "The impact of the Data Quality Act on environmental regulatory science." In *Proceedings of the 2005 NGWA Ground Water and Environmental Law Conference, Baltimore, MD, July 21-22*. p16-29.

Maney, JP; Wait, AD. 2005. "The role of representativeness in the project life cycle." *Environ. Forensics* 6:17-19.

Mattuck, RL; Blanchet, RJ; Wait, AD. 2005. "Data representativeness for risk assessment." *Environ. Forensics* 6:65-70.

Wait, AD. 2003. "Letter to the editor: Understanding the Data Quality Act." *Chem. Eng. News* 81(6):4-5.

Wait, AD. 2003. "Scientific evidence in the courtroom." *Trends – Risk Science & Applications* 27:1-2.

Wait, AD. 2002. "Challenges in producing defensible environmental chemistry measurements for litigation." *Environ. Claims J.* 14:415-454.

****This paper was recommended reading for Wayne State University's Law School Dispute Resolution Program (2003) and the Harvard University Extension Environmental Management Program (2004-2005).**

Wait, AD. 2001. "Environmental forensic chemistry and sound science in the courtroom." *Fordham Environ. Law J.* 12:293-327.

Wait, AD. 2000. "Evolution of organic analytical methods in environmental forensic chemistry." *Environ. Forensics* 1:37-46.

Brilis, GM; Worthington, JC; Wait, AD. 2000. "Quality science in the courtroom: US EPA data quality and peer review policies and procedures compared to the Daubert factors." *Environ. Forensics* 1:197-203.

****This paper received US EPA's FY 2001 Scientific and Technological Achievement Award (see US EPA Scientific Advisory Board report EPA-SAB-EC-03-003, December 2002).**

Wait, AD; Cook, LL. 1999. "Opportunities in environmental forensic chemistry analysis." *Environ. Test. Anal.* 8(4):31-32.

Wait, AD. 1999. "Evolution of organic analytical methods in environmental forensic chemistry." *Int. J. Environ. Forensics* 1(1):68-86.

Wait, AD; Butler, EL. 1999. "Forensic chemistry: Tools for discerning site liability." *Environ. Compliance & Litigation Strategy* 14(9):4-5.

Wait, AD. 1999. "Non-petroleum forensic chemistry." *Trends in Risk & Remediation* 16:4-5.

Slayton, TM; Valberg, PA; Wait, AD. 1998. "Estimating dermal transfer from PCB-contaminated porous surfaces." *Chemosphere* 36(14):3003-3014.

Wait, AD. 1997. "Appendix A: Data Usability Report for PCB Congeners High Resolution Coring Study/Appendix B: Data Usability Report for PCB Congeners Water Column Monitoring Study." In *Phase 2 Report, Volume 2C – Data Evaluation and Interpretation Report (DEIR), Hudson River PCBs Reassessment RI/FS*. Report prepared on behalf of TAMS Consultants, The CADMUS Group, and Gradient Corporation. Submitted to US EPA Region II.

Butler, EL; Frisbie, SH; Schabron, JF; Sorini, SS; Wait, AD. 1997. "New ASTM TPH screening method." *Environ. Lab* 9(1):11-14.

Wait, AD; Cook, LL. 1997. "Analytical issues for persistent organic compounds." *Trends in Risk & Remediation* 5:5-6.

Chapnick, SD; Sharma, M; Wait, AD. 1996. "Misuse of TCLP methods." *Environ. Lab* 8(1):22-25.

Wait, AD; Douglas, GS. 1995. "QA for nonstandard analytical methods." *Environ. Lab* 7(6):30-34.

Wallin, BK; Hamilton, EJ; Wait, AD. 1994. "Minimizing data quality liability." *Environ. Lab* 6(4):19-22.

Wait, AD; Bowers, TS. 1993. "The intrinsic value of nondetects." *Environ. Lab* 5(1):20-23.

Sauter, A; Wait, AD. 1992. "Perspectives on data integrity and quality." *Environ. Lab* 4(3):25-33.

Maney, JP; Wait, AD. 1991. "The importance of measurement integrity." *Environ. Lab* 3(5):20-25.

Chrostowski, J; Wait, AD; Kwong, E; Jefferies, A. 1985. "Assessment of organic contaminants in emissions from refuse-derived fuel combustion." US EPA Report No. EPA/600/2-85/155.

Boehm, PD; Wait, AD; Fiest, DL; Pilson, D. 1982. "Ixtoc oil spill assessment: Chemical assessment-hydrocarbon analyses." Final Report, Bureau of Land Management (BLM) Contract No. AA851-CTO-71.

Wait, AD; Abell, P. 1982. "N-Alkane and fatty acid stratigraphy of the Lake Turkana Basin, Kenya." *Org. Geochem.* 4:37-50.

Wait, AD; Kwong, E; Jefferies, A; Rodgers, C; Moseman, N. 1982. "Assessment of organic contaminants in emissions from refuse-derived fuel combustion." Final Report, US EPA Contract No. 68-03-2771.

Perry, G; Silvestro, E; Wait, AD. 1980. "An investigation into herbicide usage on Boston Edison Right-of-way #4 in Weymouth, Massachusetts." Special report published by Boston Edison Company.

Wait, AD. 1979. "Organic molecular stratigraphy of the Lake Turkana Basin, Kenya [Dissertation]." University of Rhode Island, Kingston, RI.

Wait, AD. 1977. "Preparation of Glass Capillary Gas Chromatography Columns." University of Rhode Island Department of Chemistry Report, September.

Presentations – *Author*

Tcaciuc, AP; Kneeland, JM; Wait, AD. 2018. "Natural Gas Condensate Forensics: A Case Study." Presented at the 34th Annual International Conference on Soils, Sediments, Water and Energy, AEHS Foundation, UMASS, Amherst, MA, October 17.

Rice, JW; Hansen, BC; Wait, AD. 2018. "Potential Adulteration Issues Associated with Edible Cannabis Products." Presented at the IFT (Institute of Food Technologists) 18 Conference, Chicago, IL, July 16.

Wait, AD. 2017. "Data Quality in Natural Resources and Environmental Damage Litigation." Presented at the Ad-Hoc Industry Natural Resource Management Group Webinar, Cambridge, MA, May 24.

Wait, AD. 2017. "Marine Oil Spill Data Quality." Presented at the Gradient NRD Webinar, Cambridge, MA, February 16.

Wait, AD. 2017. "Methods Harmonization" and "Whole Effluent Toxicity (WET) Testing." Presented at the Environmental Laboratory Advisory Board Session of the Forum on Environmental Accreditation Conference, Houston, TX, January 23.

Wait, AD. 2016. "Methods Harmonization." Presented at the Environmental Laboratory Advisory Board Session of the Forum on Environmental Accreditation Conference, Tulsa, OK, January 25.

Wait, AD. 2015. "Methods Harmonization." Presented at the Environmental Laboratory Advisory Board Session of the National Environmental Monitoring Conference, Chicago, IL, July 13.

Wait, AD. 2008. "Strategies for Monitoring Adulterants." Presented at the American Herbal Products Association (AHPA) Membership Roundtable Meeting, Anaheim, CA, March 13.

Wait, AD. 2008. "Ensuring Integrity of the Supply Chain – Case Studies." Presented at the Council for Responsible Nutrition (CRN) and Virgo Webinar, February 19.

Wait, AD. 2008. "Dietary Supplements – Regulated but Unenforced, Good to Eat?" Presented at the Gradient Seminar Series, Cambridge, MA, September 24.

Wait, AD. 2007. "Adulterants: An Industry Testing Dilemma." Presented at the Regulations for Nutraceuticals 2007 Conference, Washington, DC, October 19.

Wait, AD. 2007. "An Environmental Overview of Alkylphenol Ethoxylates [Plenary Session]." Presented at the 2007 NGWA Ground Water and Environmental Law Conference, Dublin, OH, July 25.

Wait, AD. 2005. "The Impact of the Data Quality Act on Environmental Regulatory Science [Plenary Session]." Presented at the 2005 NGWA Ground Water and Environmental Law Conference, Baltimore, MD, July 21.

Wait, AD. 2004. "Forensic Environmental Chemistry." Presented at the Harvard University Extension Environmental Management Program, Cambridge, MA, October 18.

Wait, AD. 2004. "Forensic Chemistry Tools for Environmental Investigations." Presented at the University of Rhode Island Chemistry Department Seminar Series, Kingston, RI, April 19.

Wait, AD. 2003. "Implications of the Data Quality Act." Presented at the Independent Testing Laboratory Association (ITLA) Quarterly Meeting, Waltham, MA, September 10.

Wait, AD. 2002. "Challenges in Producing Defensible Environmental Forensic Chemistry Measurements." Presented at the Camp Dresser & McKee (CDM) Professional Seminar Series, Cambridge, MA, November 19.

Wait, AD; Reid, KR. 2002. "Producing Defensible Environmental Forensic Chemistry Measurements." Presented at the Environmental Forensic Chemistry Session of the 224th American Chemical Society (ACS) National Meeting – Division of Chemistry & The Law, Boston, MA, August 20.

Butler, EL; Wait, AD; Douglas, G; Brown, J. 2001. "Tiered Analytical Approach is a Versatile and Cost Effective Tool in Answering Forensic Questions." Presented at the First International Congress on Petroleum Contaminated Soils, Sediments & Water, Imperial College, London, England, April 16.

Wait, AD. 2001. "Producing Defensible Pesticide Data." Presented at the NYSDEC Workshop, Defensible Investigation & Sampling Techniques for the Pesticide Control Specialist, Albany, NY, April 24-26.

Wait, AD. 2000. "Environmental Forensics – Chemistry Techniques for Discerning Contaminant Liability." Presented at the Environmental and Occupational Health Sciences Institute's (EOHSI) Seminar Series, Rutgers University, Piscataway, NJ, October 12.

Sorini, SS; Schabron, JF; Bowes, JR; Frisbee, SH; Butler, EL; Wait, AD. 2000. "Field Application of ASTM Method D5831 at Fuel-contaminated Sites." Presented at US EPA's 16th Annual Waste Testing & Quality Assurance Symposium, Arlington, VA, August 8.

Wait, AD. 2000. "Environmental Forensic Chemistry and Quality Science in the Courtroom." Presented at the Memphis Bar Association, Environmental Law Section, TN, March 24.

Wait, AD. 2000. "Environmental Forensic Chemistry." Presented at the IT Group Technology and Information Exchange Seminar, Rocky Hill, CT, February 3.

Butler, EL; Wait, AD. 1999. "Forensic Applications of Petroleum Hydrocarbon Fingerprinting at a Wood Treating Site." Presented at the IT Group's Environmental Solutions Exchange Conference 1999, Orlando, FL, February 4-6. Also presented at the IBC Environmental Forensics Conference, Washington, DC, June 24.

Slayton, TM; Valberg, PA; Wait, AD. 1998. "Estimating Dermal Transfer from PCB-contaminated Porous Surfaces." Presented at the 37th Annual Meeting of the Society of Toxicology, Seattle, WA, March 1-5.

Wait, AD; Bradley, A. 1997. "Data Quality Management." IT Corporation Corporate Technical Training Seminar, Cambridge, MA, January 16.

Wait, AD. 1994. "Quality Control Aspects of Ambient Air Monitoring." Presented at the Quality Assurance Environmental Decision Making Conference, Yorktown Heights, NY. Sponsored by US EPA Region II and New York Water Environmental Association.

Wait, AD; Chapnick, SD. 1994. "Contract Laboratories and Data Assessment [Short Course]." Presented to OXY USA Environmental Site Remediation Managers, Tulsa, OK, September 7.

Shifrin, NS; Wait, AD. 1994. "Environmental Chemistry [Short Course]." Presented to Anitec (Division of International Paper) Environmental Managers, Binghamton, NY, May 6.

Chapnick, SD; Wait, AD. 1993. "Data Quality Management [Short Course]." Presented to ARCO Environmental Site Remediation Managers, Los Angeles, CA, August 20.

Wait, AD; Shifrin, NS; Chapnick, SD. 1992. "Ensuring Environmental Data Quality [Invited Paper 92-122.5]." Presented at the 85th Annual Air and Waste Management Association (AWMA) Meeting, Kansas City, MO, June 21-26.

Chiu, KS; Wait, AD; Maney, JP; Poppiti, JA. 1985. "The Characterization of Polycyclic Aromatic Compounds in Petroleum [Paper No. 382]." Presented at the Pittsburgh Conference on Analytical Chemistry and Applied Spectroscopy.

Wait, AD; Jefferies, A; Kwong, E; Wright, C; Smith, R; Poppiti, J. 1985. "Evaluation of Extraction Procedures for the Characterization of Hazardous Wastes." Presented at LABCON WEST 85, San Mateo, CA.

Wait, AD; Jefferies, AR. 1981. "Priority Pollutant Content of Union Camp Wastewater in Franklin, Virginia [including an analytical chemistry primer]." Presented to the Virginia State Water Board, Richmond, VA.

Presentations – *Chair/Organizer*

Wait, AD. 2018. Chaired Environmental Forensic Session at the 34th Annual International Conference on Soils, Sediments, Water and Energy, AEHS Foundation, UMASS, Amherst, MA, October 17.

Wait, AD. 2018. Chaired Environmental Laboratory Advisory Board Session at the NELAC Forum on Environmental Accreditation, New Orleans, LA, August 6.

Wait, AD. 2017. Chaired Environmental Laboratory Advisory Board Session at the NELAC Forum on Environmental Accreditation, Houston, TX, January 23.

Wait, AD. 2016. Chaired Environmental Forensic Session at the 32nd Annual International Conference on Soils, Sediments, Water and Energy, AEHS Foundation, UMASS, Amherst, MA, October 19.

Wait, AD. 2016. Chaired Environmental Laboratory Advisory Board Session at the Environmental Measurement Symposium, Orange County, CA, August 8.

Wait, AD. 2015. Organized Environmental Forensic Session at the 31st Annual International Conference on Soils, Sediments, Water and Energy, AEHS Foundation, UMASS, Amherst, MA, October 20.

Wait, AD. 2014. Chaired Environmental Forensic Session at the 30th Annual International Conference on Soils, Sediments, Water and Energy, AEHS Foundation, UMASS, Amherst, MA, October 21.

Wait, AD. 2013. Chaired Environmental Forensic Session at the 29th Annual International Conference on Soils, Sediments, Water and Energy, AEHS Foundation, UMASS, Amherst, MA, October 22.

Wait, AD. 2012. Chaired Environmental Forensic Session at the 28th Annual International Conference on Soils, Sediments, Water and Energy, AEHS Foundation, UMASS, Amherst, MA, October 17.

Wait, AD. 2011. Chaired Environmental Forensic Session at the 27th Annual International Conference on Soils, Sediments, Water and Energy, AEHS Foundation, UMASS, Amherst, MA, October 19.

Wait, AD. 2010. Chaired Environmental Forensic Session at the 26th Annual International Conference on Soils, Sediments, Water and Energy, AEHS Foundation, UMASS, Amherst, MA, October 20.

Wait, AD. 2009. Chaired Environmental Forensic and Chemical Analysis Sessions at the 25th Annual International Conference on Soils, Sediments, Water and Energy, UMASS, Amherst, MA, October 21.

Wait, AD. 2008. Organized Pharmaceuticals in the Environment Session at the 24th Annual International Conference on Soils, Sediments, and Water, UMASS, Amherst, MA, October 23.

Wait, AD. 2007. Chaired Environmental Forensic Session at the 23rd Annual International Conference on Soils, Sediments and Water, UMASS, Amherst, MA, October 16.

Wait, AD. 2006. Organized Environmental Forensic Session at the 22nd Annual International Conference on Soils, Sediments and Water, UMASS, Amherst, MA, October 18.

Wait, AD. 2005. Chaired Indoor Air and Chemical Analysis Sessions at the 21st Annual International Conference on Soils, Sediments and Water, UMASS, Amherst, MA, October 20.

Wait, AD. 2004. Chaired Chemical Analysis Session at the 20th Annual International Conference on Soils, Sediments and Water, UMASS, Amherst, MA, October 20.

Wait, AD. 2003. Organized Environmental Forensic Session at the 19th Annual International Conference on Contaminated Soils, Sediments and Water, UMASS, Amherst, MA, October 20.

Wait, AD. 2002. Organized and chaired Environmental Forensic Session at the American Chemical Society National Meeting, Boston, MA, August 20.

Wait, AD. 2002. Chaired Environmental Forensics Session at the 18th Annual International Conference on Contaminated Soils, Sediments and Water, UMASS, Amherst, MA, October 24.

Wait, AD. 2001. Chaired Risk & Risk-Based Decision Making Session at the 17th Annual International Conference on Contaminated Soils, Sediments and Water. UMASS, Amherst, MA, October 25.

Wait, AD. 2000. Chaired Risk Session at the 16th Annual International Conference on Contaminated Soils, Sediments and Water, UMASS, Amherst, MA, October 18.

Wait, AD; Garcia-Surette, M. 1999. Co-chaired Risk Session at the 15th Annual International Conference on Contaminated Soils & Water, UMASS, Amherst, MA, October 19.

Appendix B

Expert Report and Testimony Experience of A. Dallas Wait, Ph.D.

A. DALLAS WAIT
Expert Report and Testimony Experience

Dr. Wait has provided testimony evaluating the source and fate of chemicals in the environment, product adulteration, the design and appropriateness of analytical methodologies, as well as for data quality, data integrity, data usability, and sample collection issues. Testimony provided includes:

1. An expert report evaluating analytical chemistry issues associated with the analysis of per- and polyfluoroalkyl substances (PFAS) in water, soil, and serum samples in the case Hula *et al*. *vs*. Wolverine World Wide, Inc. and 3M Company. Dr. Wait was retained by Mayer Brown representing 3M Company (State of Michigan, County of Kent, No. 18-00055-CZ, October 2020).

2. An expert report evaluating analytical chemistry issues associated with the analysis of per- and polyfluoroalkyl substances (PFAS) in water and serum samples in the case West Morgan-East Lawrence Water and Sewer Authority *et al*. *vs*. 3M Company, Dyneon, LLC, and Daikin America, Inc. Dr. Wait was retained by Mayer Brown representing 3M Company (Northern District of Alabama, Northeastern Division, Case No. 5:15-CV-01750-AKK, February 2020).

3. An expert report evaluating analytical chemistry issues associated with the analysis of per- and polyfluoroalkyl substances (PFAS) in water and serum samples in the case Kapp *vs*. Wolverine World Wide, Inc. and 3M Company. Dr. Wait was retained by Mayer Brown representing 3M Company (State of Michigan, County of Kent, No. 18-08616-NI, January 2020, supplemented October 2020).

4. An expert report on the historical analytical chemistry testing practices for 1,2,3-trichloropropane (1,2,3-TCP) in drinking water in the case City of Hemet *vs*. The Dow Chemical Company, Shell Oil Company *et al*. Dr. Wait was retained by King & Spalding representing Dow and Shell (Central District Court of California, Case No. CV18-2022MWF(SPx), November 2019). This case was settled in December 2019.

5. An expert report evaluating analytical chemistry issues associated with the analysis of per- and polyfluoroalkyl substances (PFAS) in water and serum samples in the case Brimmer *vs*. Wolverine World Wide, Inc. and 3M Company. Dr. Wait was retained by Mayer Brown representing 3M Company (State of Michigan, County of Kent, No. 18-01136-CZ, October 2019, supplemented October 2020).

6. An expert report evaluating analytical chemistry issues associated with the analysis of per- and polyfluoroalkyl substances (PFAS) in water and serum samples in the case Debski *vs*. Wolverine World Wide, Inc. and 3M Company. Dr. Wait was retained by Mayer Brown representing 3M Company (State of Michigan, County of Kent, No. 18-00055-CZ, September 2019). This case was dismissed in January 2020.

7. An expert report evaluating analytical chemistry issues associated with the analysis of per- and polyfluoroalkyl substances (PFAS) in water and serum samples in the case McNaughton *et al*. *vs*. Wolverine World Wide, Inc. and 3M Company. Dr. Wait was retained by Mayer Brown representing 3M Company (State of Michigan, County of Kent, No. 18-00086-CZ, September 2019). This case was settled in February 2020.

8. A deposition and jury trial evaluating the state-of-the-art evolution of organic analytical test methods for drinking water over the past 50 years focusing on the analysis of 1,2,3-trichloropropane ("1,2,3-TCP") in the case City of Atwater *vs*. Shell Oil Company, The Dow Chemical Corporation *et al*. Dr. Wait was retained by King & Spalding (representing Dow) and Steptoe & Johnson (representing Shell) (Superior Court of the State of California, County of San Francisco, No. CGC-05-441058, April, July, August 2019). This case was resolved in September, 2019.

9. An expert report and deposition evaluating opinions associated with the alleged disposal of hazardous substances at an Ohio Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) site landfill in the case Hobart Corporation *et al*. *vs*. The Dayton Power and Light Company *et al*. Dr. Wait was retained by the defendants' counsel, Polsinelli (Southern District Court of Ohio, Case No. 3:13-cv-115-WHR, July, October 2018). This case is ongoing.

10. An expert report and deposition evaluating the sampling and analysis methodologies for flushable wipes in various wastewater studies in the case City of Wyoming, Minnesota *et al*. *vs*. Procter & Gamble *et al*. Dr. Wait was retained by the plaintiffs' counsel, Saltz Mongeluzzi Barrett & Bendesky, P. C. (District Court of Minnesota, Case No. 15-cv-02101-JRT/TNL, July, August 2018). This case was settled in 2019.

11. An expert report evaluating the suitability of using the polychlorinated biphenyl (PCB) Aroclor approach (*versus* a PCB congener approach) for discerning and quantifying PCB contamination in the case Emily Nanouk *vs*. United States of America. Dr. Wait was retained by the defendant US Department of Justice (District Court of Alaska, Case No. 3:15-cv-00221-RRB, March 2018). This case was dismissed in December 2018.

12. An expert report evaluating the sampling, analysis, and reporting practices of an environmental laboratory associated with alleged fraud claims in the case Haney *et al*. *vs*. Range Resources – Appalachia, LLC *et al*. Dr. Wait was retained by the defendants' counsel, Babst Calland representing Microbac Laboratories, Inc. (Court of Common Pleas of Washington County, Pennsylvania; Case No. 2012-3534, January 2018). This case was settled in January 2018.

13. An expert report evaluating the composition of light non-aqueous phase liquid (LNAPL) present at a natural gas plant and surrounding area in response to a Hearing called by the Railroad Commission of Texas (RRC) (Oil & Gas Docket No. 09-0304555, January 2018). Dr. Wait was retained by AL Law Group, PLLC, representing Davis Gas Processing. This case was settled in March 2018.

14. An expert report and deposition regarding distinguishing the chemical differences between α-diketones (specifically 2,3-butanedione [diacetyl] and 2,3-pentanedione) and β-diketones (specifically 2,4-pentanedione) in the case Brian Tucker and Sherri Tucker *vs*. Momentive Performance Materials USA, The Dow Chemical Company, Union Carbide Corporation, *et al*. Dr. Wait was retained by the defendants' counsels, Orrick, Herrington & Sutcliffe LLP and Lewis Brisbois Bisgaard & Smith, LLP (District Court for the Southern District of West Virginia at Charleston, Case No. 2:13-cv-04480, January 2017). This case was settled in February 2017.

15. An expert report and deposition regarding the reliability and appropriateness of testing conducted to assess formaldehyde emissions from composite wood products in the case Dan Johnson *et al*. *vs*. Lumber Liquidators, Inc. Dr. Wait was retained by the defendant's counsels, McGuireWoods, LLP and Morrison & Foerster, LLP (US Eastern District of Virginia, MDL No. 1:15-md002627 [AJT/TRJ], May 2016). This case is ongoing.

16. An expert report evaluating the alleged chronic exposure to crystalline silica during the handling of silicon metal on railroad cars in the case Brown *vs*. Port of Montana Authority, Union Pacific Railroad Co., *et al*. Dr. Wait was retained by the defendants' counsel, Lamson, Dugan & Murray, LLP (Montana Second Individual District Court, Silver Bow County, Case No. DV-11-155, April 2015). This case was settled in December 2015.

17. An expert report regarding the reliability of testing results alleging the identification of diethyl-phenethylamine compounds in a *Dendrobium*-based pre-workout dietary supplement in the case Nutrition Distribution LLC *vs*. Driven Sports and Sports Nutrition Research, LTD. Dr. Wait was retained by the defendant's counsel, Wilson Elser, LLP (District Court of Central California, Case No. CV-13-06195-JAK, December 2014). This case was settled in January 2015.

18. An affidavit regarding measurement representativeness and variance needed to characterize a chemical constituent in a dietary supplement product in the case Rosenblum (Oregon Attorney General) *vs*. Innovation Ventures, LLC. Dr. Wait was retained by the defendant's counsel, Oakland Law Group (Oregon Circuit Court, County of Multnomah, Case No. 1312-17876, March 2014).

19. An affidavit regarding measurement representativeness and variance needed to characterize a chemical constituent in a dietary supplement product in the case Consumer Protection Division, Office of the Maryland Attorney General *vs*. Innovation Ventures, LLC. Dr. Wait was retained by the defendant's counsel, Oakland Law Group (Circuit Court for Baltimore City, Case No. 24-C-13-003908, December 2013).

20. An affidavit regarding measurement representativeness and variance needed to characterize a chemical constituent in a dietary supplement product in the case State of Tennessee *vs*. Innovation Ventures, LLC. Dr. Wait was retained by the defendant's counsel, Oakland Law Group (Circuit Court of Davidson County, Case No. 13C4341, November 2013).

21. A sworn deposition regarding the reliability of differing test results characterizing the purity of the pesticide product Acephate in the case Amvac Chemical Corporation *vs*. Chemstarr, LLC and Zheijiang Tide Cropscience, Co., LTD. Dr. Wait was retained by the defendants' counsel, DLA Piper (Superior Court of the State of California, Orange County, Central Justice Center, Case No. 30-2010-00425371, March 2012). This case was settled in March 2012.

22. An expert report, summary judgment declaration, and deposition regarding the reliability of test results for the alleged presence of Clenbuterol in dietary supplement products in the case of Jessica Hardy (a 2008 Olympic swimming contender) *vs*. Advocare International, LP., Custom Nutritional Labs, Inc., Arizona Nutritional Supplements, Inc., *et al*. Dr. Wait was retained by the defendants' counsel, Glaser Weil Fink Jacobs (Case No. 2:09-cv-01307-JHN [PJWx], July, August, September 2011). This case was settled in April 2012.

23. An expert report regarding the reliability of hexavalent chromium data for sludge samples tested in the 1970s in the case Osborn and Osborn *vs.* Prime Tanning Corp. *et al.* Dr. Wait was retained by the defendants' counsel, Shook, Hardy & Bacon, LLP and Lathrop & Gage, LLP (Western District Court of Missouri, Case No. 5:09-cv-06082-GAF, July 2011).

24. A sworn deposition, surrebuttal report, and affidavit regarding the reliability of sampling plan designs and testing results for hexavalent chromium (Cr^{+6}) in agricultural field and residential yard soils collected in areas where tannery sludge had been spread in the case of S. Beery and Tracy M. Johnson, *et al*. *vs*. Prime Tanning Corp. *et al*. Dr. Wait was retained by the defendants' counsel Shook, Hardy & Bacon, LLP and Lathrop & Gage, LLP (Circuit Court of Buchanan County, Missouri, Case No. 09BU-CV06421, June, August, November 2011). This litigation was settled in January 2012.

25. An expert report regarding the reliability of sampling methods and chemistry data used to allege Resource Conservation and Recovery Act (RCRA) waste handling violations for diesel fuel, gasoline, and transmix at a small refinery in the case United States of America *vs*. Mark Nicholson, *et al.* Dr. Wait was retained by the defendants' counsel, John Dietz (District Court of Arizona, Civil Action No. CIV-09-1729, June 2010). This litigation was settled in December 2011.

26. An affidavit and expert report regarding the reliability of data alleging the presence of diethylene glycol (DEG) in dog treats in the case of Waggin' Train, LLC *vs*. Normerica, Inc. and Northdown Industries, Inc. Dr. Wait was retained by the plaintiff's counsel, Quinn Emanuel Urquhart Oliver & Hedges, LLP, then Butler, Snow, O'Mara, Stevens & Cannada (Western District of Tennessee, Civil Action No. 1:09-CV-01093-JDG-egb, July 2009/February 2010). This litigation was settled in February 2010.

27. An expert report, sworn deposition, and affidavit regarding the reliability of sampling and analysis methods used for trace levels of sulfonyl urea herbicides, particularly sulfometuron methyl ("Oust"), in agricultural soils in the case of Timm Adams *et al*. *vs*. United States of America *et al*. Dr. Wait was retained by the defendants' counsel, the US Department of Justice (District Court of Idaho, Civil Action No. 4:03-CV-00049[BLW], December 2008, January/ February 2009). This case decided in favor of the defendants in January 2012.

28. An expert report, surrebuttal report, and sworn deposition regarding the reliability of sampling and analysis methods used to test for incidental polychlorinated biphenyls (PCBs), chlorinated dioxins and furans, and hexachlorobenzene in manufacturing wastes in the case United States of America *vs*. USM (Magnesium Corp. of America *et al*., MagCorp). Dr. Wait was retained by USM's counsel, Parsons Behle & Latimer (Central District Court of Utah, Civil Action No. 2:01CV0040B, April/July/September 2007). This litigation was dismissed by the Court with prejudice in favor of USM in August 2008.

29. An expert report evaluating whether the chemical profile of oil present in subsurface soils at a commercial site constitutes virgin oil or waste oil in the case of 50 Tremont Street Condominium Association *et al*. *vs*. 128 Sales, Inc. *et al*. Dr. Wait was retained by 128 Sales, Inc.'s counsel, Edwards Angell Palmer & Dodge, LLP (Middlesex Superior Court, Civil Action No. 03-00089E, October 2007). This litigation was settled in March 2008.

30. Oral testimony to the City of Sparta, Wisconsin, Planning Commission regarding possible whey dietary supplement adulteration by an ethanol manufacturing plant proposed to be constructed adjacent to the supplement manufacturing facility. Dr. Wait was retained by the plaintiff's counsel, DeWitt Ross & Stevens, in the case Century Foods International *vs*. Coulee Area Renewable Energy (CARE). This litigation was settled in October 2007.

31. Designed and conducted a forensic investigation for the alleged presence of anabolic steroids in a dietary supplement, the basis of an expert report by Dr. James S. Smith in the case MuscleTech Research and Development *et al*. *vs*. Michael Cloud (an NFL football player). Dr. Wait was retained as a consulting expert by MuscleTech's counsel, Hinkley Allen & Snyder, LLP (US District Court for the Southern District of New York, Civil Action No. 03CIV8401, September 2005). This litigation was settled in 2007.

32. Contributor to an expert analytical chemistry report characterizing the content of constituents, particularly a fungicide (chlorothalonil), contained in a sealant product in the case John & Barbara Zabilansky *vs*. American Building Restorations Products, Inc., Boston Restoration Supply, Inc., and BCB Painting, Inc. Dr. Wait was retained by the plaintiffs' counsel, McRoberts, Roberts and Rainer (Commonwealth of Massachusetts, Middlesex, SS. Superior Court – Docket No. 2001-0185, February 2003). This litigation was decided by the Court in June 2004.

33. An expert report and sworn deposition regarding perchlorate regulatory chemistry and data usability issues associated with a drinking water aquifer in southern California in the case Castaic Lake Water Agency *et al*. *vs*. Whittaker Corporation *et al*. Dr. Wait was retained by the defendants' counsel, Smiland & Khachigian and Hewitt & O'Neil, LLP (Central District of California, Case No. 00-12613 AHM[RZx], May/June 2002). This litigation was settled in spring 2007.

34. Supplemental reports and expert support to counsel in a jury trial evaluating the quality, integrity, usability, and interpretation of testing data used to assess the source of historical fuel oil spills at an operating manufacturing facility in the case Newly Weds Foods, Inc. *vs*. Westvaco Corporation. Dr. Wait was retained by Newly Weds Foods, Inc.'s counsel, Edwards & Angell (Commonwealth of Massachusetts Superior Court, Civil Action No. 99-5194, September/ November 2001, January 2002). This case was the first to be held as a jury trial under the Massachusetts Superfund Statute (*Environmental Reporter* 33[1]:48-49 [2002]). The litigation was decided by the Court in January 2002.

35. An expert report regarding benzene measurement and representative sampling issues associated with petroleum refinery wastewaters regulated under the National Emission Standards for Hazardous Air Pollutants (NESHAP; 40 CFR Part 61, Subpart FF) in the case United States (Department of Justice and US EPA National Enforcement Investigation Center) *vs.* Marathon Oil Company and Marathon Ashland Petroleum, LLC. Issues regarding fraudulent laboratory activities were significant in the case. Dr. Wait was retained by the defendants' counsel, Sidley & Austin (Southern District of Illinois, Civil Action No. 99-4023-JPG, May 2000). This litigation was settled in May 2001.

36. An expert report and sworn deposition (two days) regarding the forensic characterization of a large groundwater petroleum hydrocarbon plume located at a site in southern Texas in the cases Timely Adventures, Inc. *et al. vs.* Phillips Properties, Inc.; Timely Adventures, Inc. *et al*. *vs.* Difco Inc. *et al.*; Ernesto Garzo *et al. vs.* Phillips Properties, Inc. *et al.*; and First National Bank *et al. vs.* Phillips Properties, Inc. *et al.* Potential sources of contamination included, in part, natural gas condensates released from wellheads and pipelines, and refined gasoline. Dr. Wait was retained by the plaintiff's counsel, Reed, Carrera & McLain (District Court of Hidalgo County, Texas – 93rd Judicial District; Case Nos. C-4597-92-E, C-4596-95-D, C-4566-95-B, and C-4570-95-F, respectively; July/December 1999). This litigation was settled in June 2006.

37. A sworn deposition regarding potential sources of petroleum hydrocarbon and chlorinated hydrocarbon contamination in groundwater, capillary fringe, and vadose zone soil samples at a Michigan site in the case Granholm *et al*. (State of Michigan) *vs.* Pashcke *et al.* Hydrocarbon fingerprinting and fate chemistry were integral to this assessment. Potential sources of contamination included, in part, gasoline stations, a dry cleaner, and a petroleum fuel pipeline. Dr. Wait was retained by the counsel for one of the defendants (Buckeye Pipeline), Dickinson Wright (Michigan Oakland County Circuit Court File #94-479189-CE, February 1998). This litigation was settled in October 1999.

38. Expert opinions regarding the historical analytical chemistry practices of municipalities analyzing for solvents in drinking water, specifically trichloroethylene (TCE) and trihalomethanes (THMs), in the early 1980s in the case Baker *et al*. *vs.* Motorola, Inc. *et al*. Dr. Wait was retained by the counsel for one of the defendants (the City of Phoenix), Squire, Sanders & Dempsey and the Phoenix City Attorney's Office (Superior Court of the State of Arizona, County of Maricopa, CV92-02603, November 1997). This litigation was settled in September 2000.

39. An expert report and sworn deposition regarding data quality issues for polycyclic aromatic hydrocarbon (PAH), volatile organic, petroleum hydrocarbon fingerprinting, and carbon (^{14}C) dating data used to discern potential sources of creosote, pine tar, and petroleum constituents in soils in the case Cabot Corporation *vs.* Beazer East, Inc. *et al*. Dr. Wait was retained by Cabot Corporation's counsel, Cooke, Clancy & Gruenthal (US District Court for the Northern District of Florida, Gainesville Division, Civil Action No. 95-10044MMP, April/July 1997). This case was settled.

40. An expert report, surrebuttal report, and sworn deposition regarding the historical analytical chemistry practices of municipalities analyzing for solvents in drinking water, specifically trichloroethylene (TCE) and trihalomethanes (THMs), in the early 1980s in the case Lofgren *et al*. *vs.* Motorola, Inc. *et al*. Dr. Wait was retained by the City of Phoenix's counsel, Squire, Sanders & Dempsey and the Phoenix City Attorney's Office (Superior Court of the State of Arizona, County of Maricopa, CV93-05521, CV93-15612, CV94-08954, CV95-05322 – consolidated, April 1997, July/September 1997). The judge granted summary judgment to the defendants on the grounds of lack of admissible medical causation testimony in June 1998.

41. Jury trial testimony regarding data quality, data integrity, and sampling issues associated with a remedial investigation at the Whitestown, New York landfill in the case Douglas *et al. vs.* Town of Whitestown. Chemicals of interest included solvents and metals. Dr. Wait was retained by the Town of Whitestown's counsel, Gorman, Waszkiewicz, Gorman and Schmitt, Utica, New York (State of New York Supreme Court, County of Oneida, RJI No. 32-94-1114, August 1996, and preparation for retrial, October 1998). This case was settled on appeal.

42. An expert report and sworn deposition regarding chemistry quality assurance issues for the Lake Charles Surge Pond Resource Conservation and Recovery Act (RCRA) closure feasibility study. The sample collection and analytical chemistry program was assessed relative to the validity and integrity of data generated as part of a closure study for a 26-acre petroleum refinery holding pond in the case CITGO Petroleum Corporation *vs.* OHM Remediation Services Corporation. Chemicals of interest included petroleum hydrocarbons, solvents, and metals. Dr. Wait was retained by CITGO Petroleum Corporation's counsel, Habans, Bologna & Carriere, New Orleans, Louisiana (US District Court, Western District of Louisiana, Civil Action 94-0780, July 1996; January 1997). This litigation was successfully settled to CITGO's satisfaction in June 1997.

43. An expert report and sworn deposition regarding the historical analytical chemistry practices of analyzing for chlorinated solvents, specifically trichloroethylene (TCE) and trichloroethane (TCA), in aqueous environmental samples in the late 1960s in the case Dravo Corporation *vs.* Liberty Mutual Insurance Company and the Hartford Accident and Indemnity Company (currently under a protective order). Dr. Wait was retained by the defendants' counsels, Manta & Welge, Philadelphia, Pennsylvania, and Melito & Adolfsen, New York, New York, respectively (US District Court for the Southern District of Alabama, Civil Action 92-0674-P-C, May 1996). Melito & Adolfsen settled in April 1999, while Manta & Welge settled in April 2000.

44. An expert report and several sworn depositions (eight days) regarding the quality of data produced in numerous site investigations at an operative manufacturing facility in Los Angeles, California, in the case Kennington, Ltd. *vs.* ITT Corporation. In addition, Dr. Wait provided expert opinions regarding polychlorinated biphenyl (PCB) identifications using congener fingerprinting for the purpose of source allocation. Contaminants of concern included PCBs, chlorinated dioxins and furans, petroleum hydrocarbons, solvents, and metals. Dr. Wait was retained by ITT Corporation's counsel – initially Jones, Day, Reavis & Pogue, and then McDermott, Will & Emery, Los Angeles, California (US District Court, Central District of California, Case No. 93-7840 LEW [SX], April/May 1996, August 1997). This case was settled.

45. A sworn deposition regarding the adequacy and reliability of test methods used to characterize and fingerprint petroleum hydrocarbons in groundwater in the case The Southland Corporation *vs.* Occidental Petroleum Corporation *et al.* (US District Court for the Northern District of Texas, Dallas Division, Civil Action No. 3:93 CV-1134P, March 1995). Dr. Wait was retained by Occidental Petroleum Corporation's counsel, Baker & Botts, Dallas, Texas. This case was settled.

46. A sworn deposition regarding the analysis of chlordane in the case Luis Iglesias *vs.* Michael Blankenship and Velsicol Chemical Corp. Dr. Wait was retained by Velsicol Chemical Corp.'s counsel, Spriggs & Hollingsworth, Washington, DC (District Court of Harris County, Texas, 113th Judicial District, Case No. 89-44845, May 1994).

47. A sworn deposition regarding the analysis of carbon tetrachloride and other volatile organics in groundwater and soils. Dr. Wait critiqued the data quality of analytical work performed by the Michigan Department of Natural Resources contract laboratories at the Schoolcraft site for the case Kelley (State of Michigan) *vs.* AgraLand, Inc. *et al*. Dr. Wait was retained by AgraLand, Inc. *et al.*'s counsel, Tolley, Fisher & Verwys, Grand Rapids, Michigan (State of Michigan, County of Ingham, File No. 90-67076-CE, December 1992).

48. A sworn deposition regarding the analysis of chlordane in the case James P. Conde *vs.* SWAT Exterminators, Inc. and Velsicol Chemical Corp. Dr. Wait was retained by the defendants' counsel, Spriggs & Hollingsworth, Washington, DC (US District Court for the Southern District of Ohio, Eastern Division, Case No. C2-85-638, June 1992).

49. A sworn affidavit regarding the appropriateness and integrity of analytical methodologies employed for chlordane testing of air samples in the case Salvo *vs.* New England Pest Control Co. *vs.* Velsicol Chemical Corp. Dr. Wait was retained by Velsicol Chemical Corp.'s counsel, Spriggs & Hollingsworth, Washington, DC (Commonwealth of Massachusetts, Bristol County, Civil Action No. 21785, October 1990).

Dr. Wait provided testimony associated with numerous commercial analytical laboratory service contracts that he managed for the New York State Department of Environmental Conservation (NYSDEC), Albany, New York. Dr. Wait's NYSDEC testimony experience includes the following:

50. Jury trial testimony in the case of the State of New York *vs.* Mattiace Industries, Inc. Dr. Wait provided factual testimony relating to analytical testing performed to determine improprieties in the storage and handling of hazardous wastes, which included petroleum hydrocarbons and solvents. Testimony was provided in April 1988 at the Nassau County Court House. The prosecuting attorney was Clive Morrick, Assistant Attorney General for the State of New York's Environmental Crime Unit. Mr. Mattiace was found guilty of improperly handling and storing hazardous materials.

51. Jury trial testimony in the case of the United States *vs.* J.S. Auto Supply Company, Inc. Dr. Wait provided factual testimony relating to analytical testing performed to determine improprieties in the storage and handling of hazardous wastes, which included petroleum hydrocarbons and solvents. The deposition was conducted before a Grand Jury in July 1988 in Buffalo, New York, under the auspices of Ed Perkins from the New York State Department of Environmental Conservation (NYSDEC).

52. Deposition in the case of New York State Department of Environmental Conservation (NYSDEC) *vs.* Loeffel's Oil Company. Dr. Wait provided factual testimony relating to analytical testing performed to determine improprieties in the storage and handling of hazardous wastes, which included petroleum hydrocarbons and solvents. The deposition was conducted in December 1982 at NYSDEC's White Plains office by George Bradlaw and Herb Johnson, under the auspices of Ed Perkins from NYSDEC.